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BACKWASH TREATMENT FACILITY FOR EXCESSIVE STORM FLOW IN SANITARY SEWERS

by

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Project No. 11020 FAH

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16 ABSTRACT

The Bachman Treatment Facility was built in Dallas, Texas, to provide physical-chemical treatment to those municipal wastewater flows that during periods of heavy precipitation exceed the capacity of a downstream interceptor. The treatments provided in the facility include the addition of waste lime sludge from a nearby water purification plant, flocculation, sedimentation, tube settling, and chlorination. The facility was operated primarily to determine the benefits that might be derived from the addition of potable water treatment plant waste sludges to these excess flows since unpublished laboratory work conducted elsewhere had indicated potential benefits in terms of better suspended solids and BOD_5 removals than would result from sedimentation alone.

A sustained dry spell coupled with the City's highly effective sewer infiltration control program resulted in increasingly infrequent operation of the facility. In order to accomplish the needed evaluation, artificially high flows were created by admitting to the sewer system a combination of water from a natural creek plus potable water from a hydrant. The results showed no benefit from the addition of potable water treatment plant waste sludges to these artificial flows, but the few times the plant operated on genuinely occurring excess flows, possible benefits were observed.

Bacterial viruses were demonstrated to be rather refractory to the combined chlorine residuals and contact time used, and also showed a high sensitivity as indicators of pollution from the facility.

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FOREWORD

The US Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The deleterious effects of storm sewer discharges and combined sewer overflows upon the nation's waterways have become of increasing concern in recent times. Efforts to alleviate the problem depend upon characterization of these flows in both a quantity and quality sense and investigation of new and improved techniques for handling/treating these flows. This report describes the application of a physical - chemical treatment system to alleviate pollution caused by excessive storm flow in a sanitary sewerage system.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory

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ABSTRACT

The Bachman treatment facility was built in Dallas, Texas, to provide physical-chemical treatment to those municipal wastewater flows that during periods of heavy precipitation exceed the capacity of a downstream interceptor. The treatments provided in the facility include the addition of waste sludge from a nearby potable water purification plant, flocculation, sedimentation, tube settling, and chlorination. The facility was operated primarily to determine the benefits that might be derived from the addition of potable water treatment plant waste sludges to these excess flows since unpublished laboratory work conducted elsewhere had indicated potential benefits in terms of better suspended solids and BOD_5 removals than would result from sedimentation alone.

The vagaries of weather (a sustained dry spell) coupled with the City's highly effective sewer infiltration control program resulted in increasingly infrequent operation of the facility. In order to accomplish the needed evaluation, artificially high flows were created by admitting to the sewer system a combination of water from a natural creek plus potable water from a hydrant. The results showed no benefit from the addition of potable water treatment plant waste sludges to these artificial flows, but the few times the plant operated on genuinely occurring excess flows, possible benefits were observed. Even in the latter case, however, additional treatment was indicated as necessary to reduce both suspended solids and dissolved organics. Additional study is therefore indicated utilizing coagulants and powdered activated carbon.

Bacterial viruses were demonstrated to be rather refractory to the combined chlorine residuals and contact time used, and also showed a high sensitivity as indicators of pollution from the facility.

Grit removal facilities were demonstrated to be a desirable component of such a plant, and odor was not a problem. Tube settlers were not demonstrated to be any more effective than sedimentation alone in the short runs and at a low hydraulic loadings observed.

This report is submitted as part of Grant No. 11020 FAW by the City of Dallas, Texas Water Utilities under sponsorship of the U.S. Environmental Protection Agency.

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SECTION I

CONCLUSIONS

1. Hydraulic observations of the Upper East-Bank Sewer System indicate that extraneous flows enter the system by both direct entry as well as by leakage from groundwater when the groundwater level builds up and submerges the sewers.

2. Of the two modes of entry, leakage of groundwater respresents the largest volumetric addition because it is of much longer duration.

3. Peak flows following an intense rainfall reach the site of the treatment facility approximately 2-3 hours after peak precipitation.

4. Although dry-weather hydraulic observations demonstrate a high degree of predictability in sewer flow, the organic measurements, (BOD_5, COD) showed a high degree of unpredictability and wide variation. The variation was such as to render chlorination very difficult to control.

5. Chlorinated wastewaters exposed in the facility do not impose an odor problem even when held overnight in a quiescent state.

6. Grit removal is an essential part of this particular facility.

7. No benefit could be attributed to tube settlers in these studies. However, the hydraulic loadings employed were low and the runs were short, and these constraints are believed to have prevented an adequate evaluation of tube settlers.

8. Waste lime sludge from the water treatment plant contributed to the suspended solids content of facility effluent. It did not contribute BOD_5 and might have resulted in a very slight removal of COD.

9. Polymers demonstrated a promise in reducing suspended solids. The polymer feed equipment was inadequate to fully evaluate polymer applications in this study.

10. The cost of water treated in the facility using polymers at 5 mg/l is calculated to be $144.48 for 1,000,000 gallons (3785 M3).

SECTION II

RECOMMENDATIONS

1. It is recommended that any future construction of facilities such as the Bachman Treatment Facility for excessive storm flow in sanitary sewers not be undertaken until detailed inflow and infiltration analyses of the contributory sewerage system are completed.

2. The concept of a pollution control facility as described herein appears quite sound, but an adequate evaluation particularly at higher flow rates must yet be made. It is recommended that the Bachman Facility continue to be systematically operated at every opportunity until high-flow evaluation is achieved. All reports of any operation should be made promptly to State and Federal agencies.

3. The use of waste lime sludges from water treatment plants to process wastewaters such as described herein appears to offer little promise -- if any. A difficult operational problem is posed in trying to control the waste lime sludge addition. It is recommended that any future test of such a treatment include the use of automatic solids measuring devices.

4. The wide variation in organic quality and hence in chlorine-demanding substances renders chlorination control a most difficult task. Any future applications should include automatic chlorination equipment.

5. Sedimentation per se comes close to achieving the quality of effluent needed. The use of polymers alone and in combination with powdered activated carbon (not studied herein) should be tested in future applications at this plant.

SECTION III

INTRODUCTION

A northwestern area of the City of Dallas is served by the East-Bank Interceptor, a 7-mile (11.3-km) long structure with a capacity at its entrance calculated to be 97.6 MGD (1647 cps). The interceptor conducts wastewaters from the East Bachman Creek, Bachman Creek, Joe's Creek, Lotot Branch, and several minor sewer systems to the Cadiz Street Pumping Station which then pumps the wastewaters to the Central Plant. The interceptor comprises the following elements, all reinforced concrete pipe:

11,135 ft (3,394 m) of 6 ft (182.4 cm) diameter,
12,187 ft (3,713 m) of 6 ft (182.9 cm) diameter,
6,326 ft (1,928 m) of 6½ ft (198.1 cm) diameter, and
7,368 ft (2,246 m) of 7½ ft (228.6 cm) diameter pipe.

Figure 1 is a diagrammatic representation of the upper contributory system which is collectively called the Upper East-Bank Sewer System.

During wet weather, the Upper East-Bank System has the capability of delivering as much flow to the interceptor as the interceptor can accommodate. At the time of the studies reported herein, the Bachman Creek system discharged into the lower end of the East Bachman Creek system as indicated by the arrows in Figure 1. The result was periodic wet-weather surcharges. Construction of a relief system for the Bachman Creek flow was undertaken as well as a polymer injection facility. Completion of these projects would result in even more water being delivered to the interceptor during wet weather. Completion of a future 60-in (182.4-cm) line would result in a 63 MGD (2759 lps) delivery to the interceptor.

The City faced the choice of constructing an additional parallel interceptor or a treatment facility which would provide chemical-physical treatment to those excess flows which were calculated to occur on the average only 22 days per year. The type of plant used in the cost comparisons is discussed in detail in Section VI, and it was economically favorable by $642,200. In arriving at this figure, it was assumed that sewer structural life was 80 years and plant structural life was 40 years. Present worth values for annual costs were calculated for 80 years and 4.5 percent interest. The present worth of replacement of the facility was calculated for 40 years hence to make an 80-year equivalent economic study period. Estimates for operation, maintenance, and personnel were included. Hence, the City elected to build the Bachman Treatment Facility to provide treatment to the excess flows. Its location is shown in Figure 2.

The facility is designed and built to accommodate experimentation, since it is located only 1250 ft (381 m) from the 154 MGD (6745 lps)

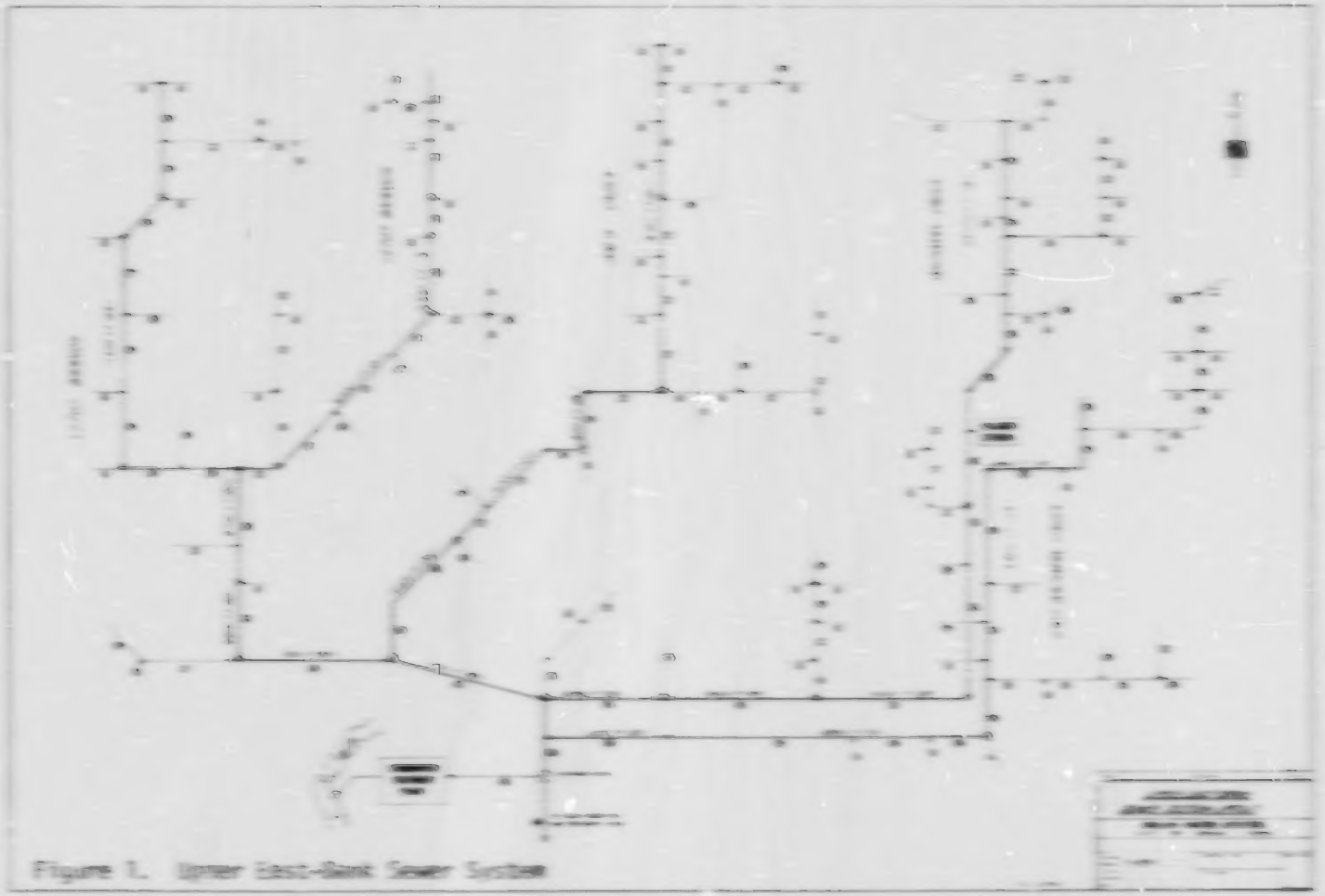


Figure 1. Upper East-Bank Sewer System

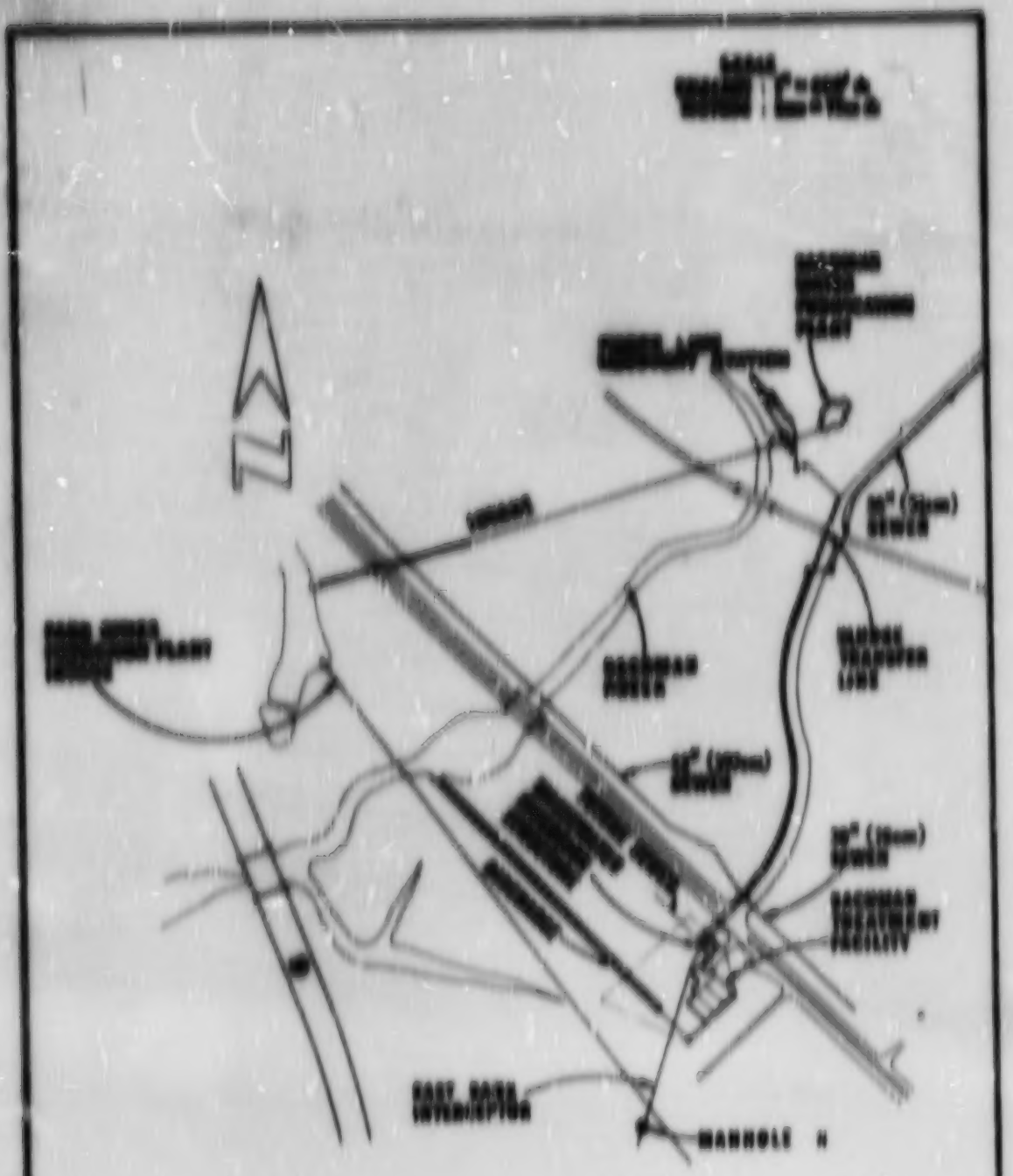


FIGURE 8. TREATMENT FACILITY AND COMPONENTS

Rechman Water Purification Plant, facilities were installed to permit a full-scale evaluation of the use of water treatment waste sludges in the treatment of the raw flows. These facilities are also discussed in Section VI (see also Figure 2).

While the facility was still under construction, preliminary work was conducted to (1) hydraulically characterize the flows and (2) to determine the wastewaters' quality characteristics. These are reported in the next two sections, respectively.

SECTION IV

HYDRAULIC CHARACTERISTICS OF SEWER FLOWS

The soils of the drainage areas served by the network of sewers are of a troublesome type to sewer construction and maintenance. Predominantly Houston Clay (1), an approximate breakdown would be:

	Percent
Houston Black Clay	53.0
Houston Clay, Regular phase	1.0
Houston Clay, Shallow phase	33.0
Trinity Clay	1.0
Lewisville Clay	6.7
Bell Clay	6.0
Fine Sandy Loam	0.3
	100.0

Houston clays have considerable moisture manifestations. They belong to Hydrologic Soil Group "D", which includes soils having the lowest infiltration capacity. However, during dry weather they shrink and crack, and subsequent precipitation enters these cracks often penetrating to the underlying Austin Chalk. Upon substantial wetting, they lose structural strength and become plastic and sticky. These properties present enormous problems to local construction contractors.

A lengthy antecedent dry-weather condition allowed for the accumulation of a substantial record of dry-weather flows in the interceptor. The flows were obtained by Sanitary Sewer Division personnel using a bubbler-tube gage installed in a manhole on the interceptor approximately 500 ft. (152 m) downstream from the site of the diversion structure (point A on Figure 2), and calculated by Manning's equation using a constant "n" of 0.013. The calculated flows are shown in Table A-1 of the Appendix.

The dry-weather flow calculations indicated the diurnal pattern to be rather predictable. A typical flow curve is shown in Figure 3. Saturday and Sunday flow patterns are somewhat similar to the weekday pattern except that the morning increase occurs about an hour later on both days, while the mid-day peak is about 0.7 MGD (30.7 lps) lower on a Saturday and 1.6 MGD (70.1 lps) lower on a Sunday.

The Bachman Branch Watershed (Figure 4) is well-instrumented for precipitation and runoff measurements and lies within the area served by the Upper East-Bank Sewer System. Two rain gages, 18 and 20 on Figure 4, are U. S. Geological Survey (USGS) instruments that are properly located and maintained. The official National Weather Service

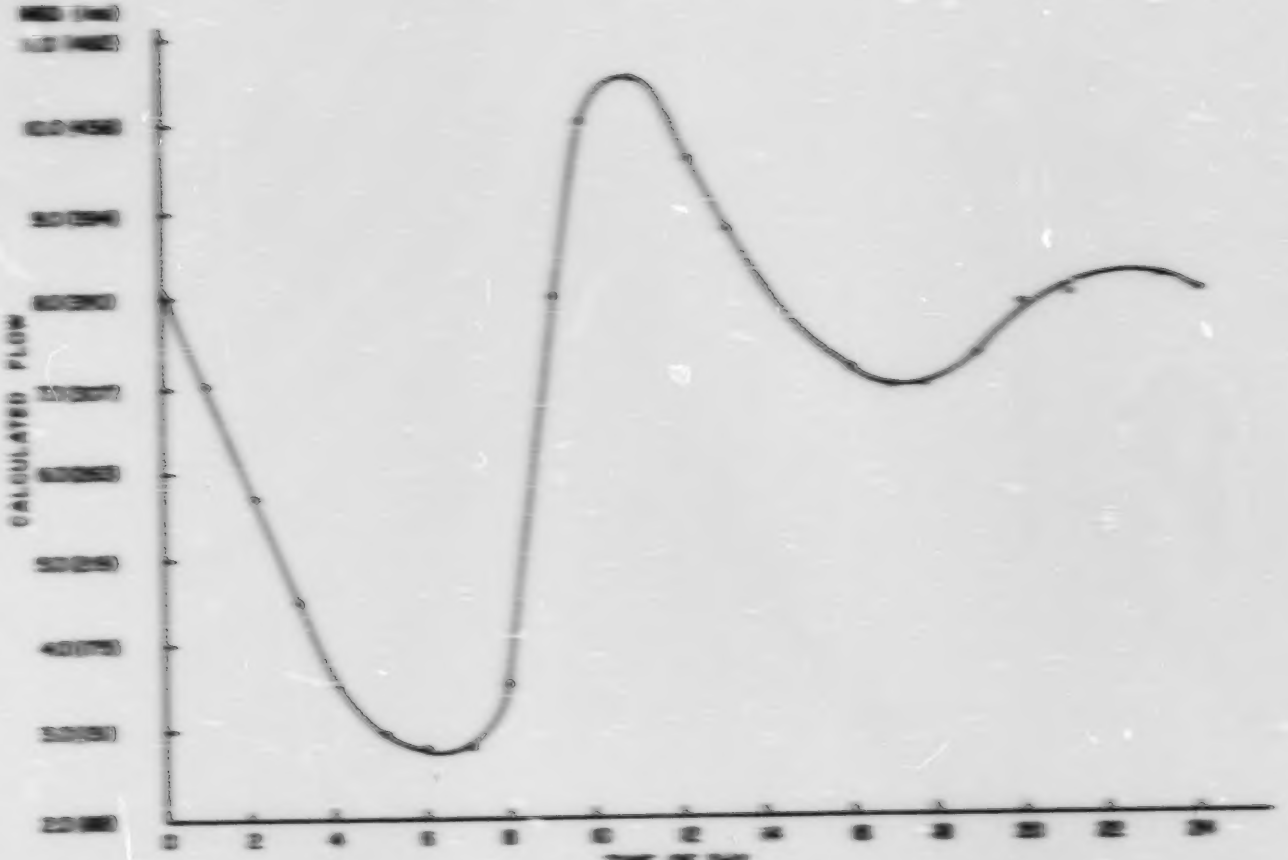


FIGURE 3. TYPICAL DRY-WEATHER DIURNAL FLOW

FIGURE 4. BACHMAN BRANCH WATERSHED

rain gage at Love Field is located just outside the watershed boundary. Two other rain gages, 27 and 41 on Figure 4, were questionably located among buildings and in a state of disrepair, and therefore their results were not used. The USGS also maintains a stream gaging station on Bachman Branch indicated by the triangle on Figure 4. The contributory area to the gaging station is 9.58 square miles (2481 ha).

Rainfall and runoff patterns for the Bachman Watershed were compared with interceptor flows to obtain some estimates of how these patterns might influence sewer flow. The precipitation period analyzed occurred at varying intensities over April 16-20, 1970, but the amount appeared fairly uniformly distributed over the basin. The record of precipitation for all five rain gages in inches (mm) was as follows:

	April			
Station	16	17	18	20
18	0.68 (17.3)	1.14 (29.0)	0.09 (2.3)	0.41 (10.4)
28	0.70 (17.8)	1.11 (28.2)	0.10 (2.5)	0.40 (10.2)
NWS	0.87 (22.1)	1.06 (26.9)	0.04 (1.0)	0.42 (10.7)
41	0.55 (14.0)	1.37 (34.8)	0.00 (0.0)	0.37 (9.4)
27	0.52 (13.2)	2.45 (62.2)	0.00 (0.0)	0.37 (9.4)

Applying averages of the first three stations uniformly onto the gaging station's contributory area results in the following total water volumes of precipitation by day:

Date	Day of Week	Volume, acre-ft (m^3)	
16	Friday	383	(472,431)
17	Saturday	564	(696,694)
18	Sunday	39	(50,456)
20	Tuesday	210	(258,418)

The hydrographs generated at the Bachman Branch gage are shown in Figure 5. The depths of the sewage flow in the interceptor at the bubbler-tube measuring site for these same days are shown in Figures 6-13, along with the hourly intensities of rainfall as measured by the NWS rain gage.

In comparing the various data, the following observations are apparent:

1. Surface runoff for April 16 peaked in the 20th hour (Figure 5), whereas precipitation was maximum in the 17th - 18th hours (Figure 6)-- a 2-3 hour delay. The maximum difference between the observed depth of flow in the interceptor for this same day and that which might have been expected on a normal dry-weather Friday also occurred in the 20th hour (Figure 6). In

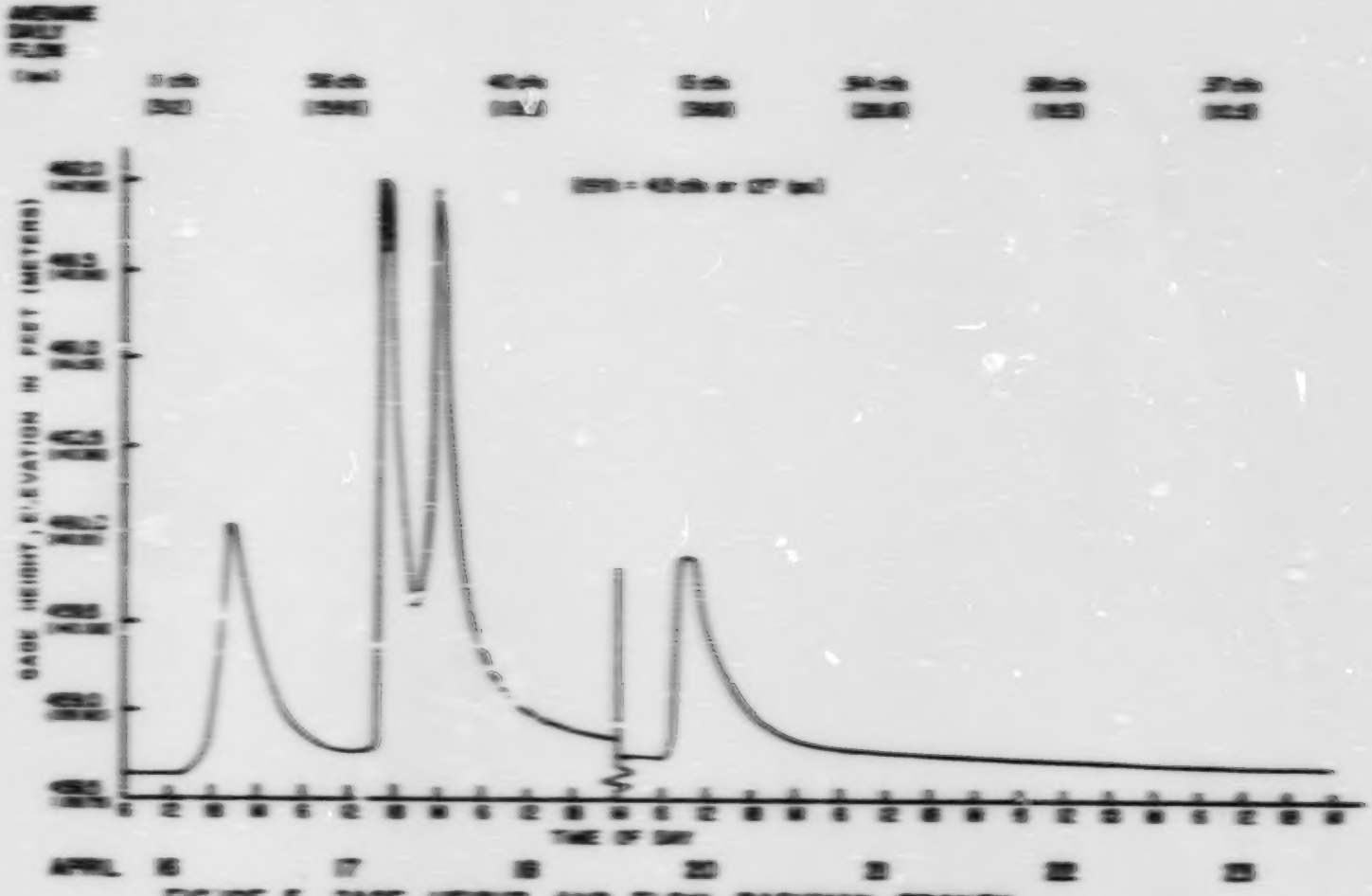


FIGURE 5. GAGE HEIGHT AND FLOW, BACHMAN BRANCH

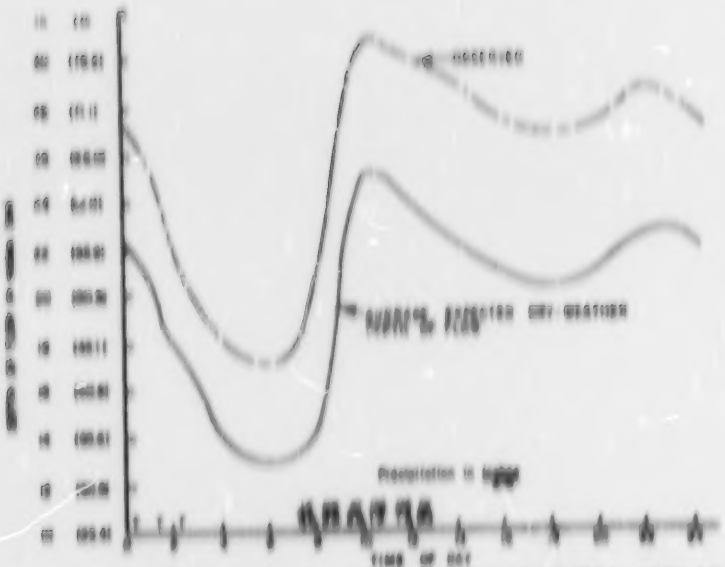


FIGURE 10 DEPTH OF FLOW IN INTERCEPTOR, TUESDAY, APRIL 00, 1971

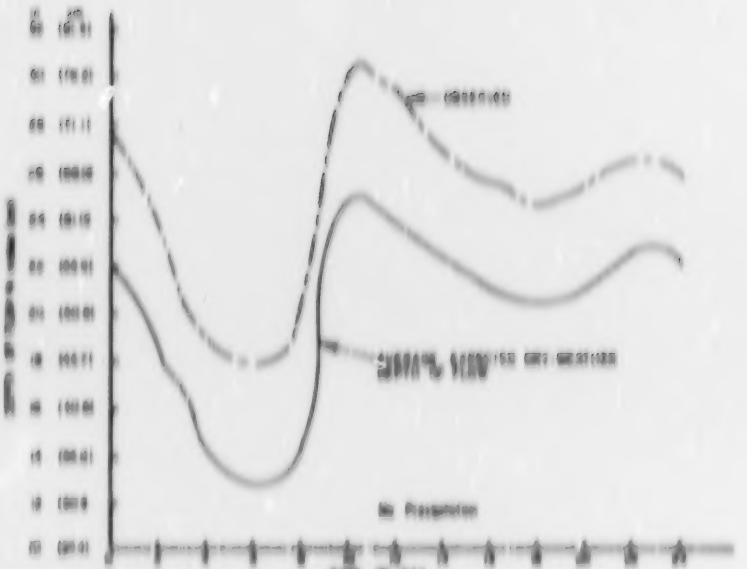


FIGURE 11 DEPTH OF FLOW IN INTERCEPTOR, WEDNESDAY, APRIL 01, 1971

other words, it took about the same time for the mass of runoff water to peak at the stream gaging station as it did for sewer flow (judged by depth) to peak at the sewer gaging station. The general similarity in time indicates a direct entry method of some rainfall entering the sewer system.

f. Substantial rains fell in the 15th hour and again in the 22nd and 23rd hours on April 17th (Figure 7). The Bachman gaging station (Figure 5) shows the 6-hour separation of the two main peaks. Judging from the gaging station, the 0.35-inch (8.9 mm) rain that fell in the 15th hour came in two sharp downpours just a few minutes apart. The gaging station peaks for April 17th occur closer to two hours after peak rainfall rather than three hours and is believed to reflect wetter soil conditions than those that prevailed on April 16th at which time the soils were quite dry. The sewer depth-of-flow chart (Figure 7) for the 17th lacks a similar definition, but it appears to respond to the 0.35-inch (8.9 mm) rainfall at about the 18th-19th hours. From this time on, the depth-of-flow curve is massively different from the expected dry-weather curve, reflecting the influence of a high groundwater table which has inundated the sewers and reflects groundwater infiltration into the sewer system. The rainfall of 0.22-inch (5.6 mm) in the 22nd-23rd hours on the 17th appears as a 0200 peak on the 18th (Figure 8), again indicating an approximate 3-hour delay.

These flow observations indicate that entry of waters from precipitation into the sewer system is both direct and indirect (through groundwater infiltration). The direct entry component seems to be reflected by the flow (depth) peaks. But the largest volume of infiltrated flows appears to derive from the groundwater infiltration component. These observations are important with respect to chemical treatment of the flows since there is likely to be a considerable difference in the quality of infiltrating waters depending upon their route of entry, direct entry flows having less opportunity to pick up dissolved minerals.

In any event, it is obvious that operating personnel for the treatment facility should be on duty within two hours of a major downpour.

SECTION V

CHARACTERIZATION OF WASTEWATERS

While the Bachman Treatment Facility was still under construction, sampling was conducted at the still incomplete diversion structure to characterize the wastewaters. Sanitary Sewer Division personnel conducted the tasks of flow measurement (calculated from bubbler-tube depth using Manning's equation as discussed in Section IV), sample collection, temperature measurement, and the acid-fixing of a dissolved oxygen (DO) sample utilizing the Hach Co. kit. Because of the approximate one-hour theoretical detention period of the facility's sedimentation basins, samples consisted of three parts, one-third taken at the beginning of an hour, one-third half-way through the hour, and a final third at the end of the hour. Such a three-part sample was collected each four hours every other day during most of the month of April 1971. In the event that substantial precipitation occurred, the sampling crews were instructed to augment their sampling program by also collecting hourly grab samples in between their scheduled samples as well as to sample daily. Such precipitation did occur as discussed in Section IV on the 16th, 17th, 18th, and 20th days of April.

The samples were delivered to the laboratory of the Bachman Water Purification Plant where Purification Division personnel titrated the acid-fixed DO sample and ran the tests for pH, conductivity, alkalinity, settleable solids, and chlorides, and also to the laboratory of the Wastewater Treatment Division where the remaining analyses were performed. For the month of April, these analyses included chemical oxygen demand (COD), 5-day 20°C biochemical oxygen demand (BOD_5), total suspended solids (SS), and methylene blue active substances (MBAS). Standard Methods procedures (2) were used throughout except where noted (as with the DO procedure).

The results of the calculated flows and the three-part hourly samples are presented in Tables A-2 to A-9 in the Appendix. The sampling was conducted each four hours at 0000-0100, 0400-0500, 0800-0900, 1200-1300, 1600-1700, and 2000-2100 hours and then again a final sampling at 2400-0100 hours in order to observe how much variation might occur with respect to 24 hours earlier. The average values ($\bar{x}$) for each day are also presented in the tables. The 2400-0100 hour samples were not included in the averaging unless, of course, a 0000-0100 hour sample was missed for some reason.

The data for April were examined to observe:

1) patterns of diurnal variation,
2) differences between wet-weather flow quality and dry-weather flow quality, and
3) a clue as to which parameter might most nearly estimate the magnitude of infiltrating flows.

A plot of the average observed flows ($\bar{X}$ values from Table A-2) is shown in Figure 14. It is apparent from this figure that flows on the 5th, 17th, 19th, 21st, and 23rd are clearly above those of the remaining days. These were therefore grouped as wet-weather flows and the remainder were grouped as dry-weather flows.

Each hourly value for the dry-weather days was averaged to provide an idea of average dry-weather flow quality variation. The curves generated by these values are shown in Figures 15 and 16. Curves for the organics (COD, BOD_5, and MBAS), total suspended solids, and chlorides show a sinusoidal shape, and those for alkalinity and conductivity a bell shape.

The data of the wet and dry groups (as defined above) were then collectively averaged and a ratio of wet:dry calculated:

	Wet	Dry	Ratio $\frac{\text{Wet}}{\text{Dry}}$
Flow, MGD(lps)	9.1 (399)	6.7 (293)	1.36
COD, mg/l	334	467	0.72
BOD_5, mg/l	155	179	0.87
SS, mg/l	151	190	0.79
MBAS, mg/l	2.7	3.1	0.87
Conductivity, µmhos	741	693	1.07
Alkalinity, mg/l	201	186	1.09
Chlorides, mg/l	55	60	0.92

Except for conductivity and alkalinity, all parameters show a dilution effect on the wet days. Hence, the quality of the infiltrating water must be more dilute than the wastewaters for COD, BOD_5, SS, MBAS, and chlorides, and more concentrated for conductivity and alkalinity. The conductivity and alkalinity increases are believed to reflect the nature of the calcareous soils in the region.

Although the wet-weather infiltration results in a dilution of most of the contaminants, the actual daily load according to these figures brought to the Bachman Facility would increase in every case but one -- the one being COD. The average concentration times the average flow for each of the above parameters for the two conditions, wet vs. dry, and their wet:dry ratio are:

	Wet	Dry	Ratio $\frac{\text{Wet}}{\text{Dry}}$
COD	3030.4	3128.9	0.97
BOD_5	1410.5	1199.3	1.18
SS	1374.1	1273.0	1.08
MBAS	24.67	20.77	1.19
Conductivity	6743.1	4643.1	1.45
Alkalinity	1829.1	1239.5	1.48
Chlorides	500.5	402.0	1.25

Hence, even though dilution is occurring during periods of infiltration which lowers the concentration of most of the substances, the actual daily load on the facility -- except for COD -- will be increased.

By calculation, an estimate of the average quality of the infiltrating waters can be obtained -- but only an estimate. These calculations yield:

COD	-37 mg/l
BOD_5	60 mg/l
SS	42 mg/l
MBAS	1.6 mg/l
Conductivity	875 µmhos
Alkalinity	946 mg/l as $CaCO_3$
Chlorides	41 mg/l as NaCl

The negative COD value simply shows that this estimating procedure is in error. However, it does demonstrate that the infiltrating waters are not without impurities.

Other data collected during the month which is not presented in detail in this report include the following:

	Minimum	Maximum
DO, mg/l	0.0	9.2
pH, units	7.1	7.8
Temperature, °C	20	23
Settleable solids, ml/l	1.5	20.0

The various analytical results along with the grab sample data were plotted on a time scale vs. rainfall and flow and visually screened for relationships. The only one that appeared to offer some promise was alkalinity. Chloride, the parameter generally used by Sanitary Sewer Division personnel for estimating infiltration flows, appeared more responsive to precipitation than to general infiltration (as estimated by volume of flow). Presumably, it was responding most to the dilution of direct-entry type of infiltration.

Since precipitation in the month of April was not of sufficient intensity to result in surcharged flows, it was decided to pursue the sampling activity for two additional months -- in June and July. Hopefully, surcharged flows would occur which could then be sampled intensively. Since alkalinity showed promise in estimating the magnitude of infiltration, and in the belief that this was coming from the calcareous soils, it was decided to include hardness tests. Also, it was considered desirable to include total and "dissolved" (that which passes the Standard Methods fiberglass filter used in the suspended solids test) COD and BOD_5. The wet weather grab

sampling program of April was scratched, but the sampling crews were instructed that if surcharge flows occurred in June or July intensive hourly grab sampling would be conducted daily as long as the surcharges existed. Hence, the resulting analytical program for these months included flow, total and "dissolved" COD, total and "dissolved" BOD_5, total suspended solids, total alkalinity, chlorides, total hardness, total nitrogen series (organic-N, NH_3-N, NO_2-N, & NO_3-N) total phosphorus, chlorine demand, (July only), pH, temperature, conductivity, settleable solids, and MBAS (continued only through June). The results in June for flow, total COD, "dissolved" COD, total BOD_5, "dissolved" BOD_5, total suspended solids, total alkalinity, chlorides, total hardness, total nitrogen, and total phosphorus are contained in the Appendix, Tables A-10 to A-20. Results for the month of July for flow, total COD, "dissolved" COD, total BOD_5, "dissolved" BOD_5, total suspended solids, total alkalinity, chlorides, and total hardness are contained in Tables A-21 to A-29. Other results are summarized at the end of this section.

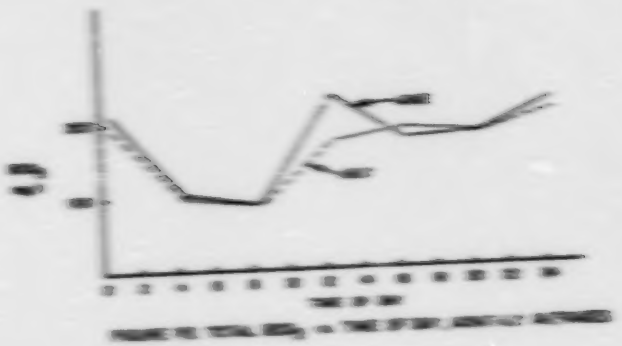
The record of precipitation for the latter part of May and for June 1971 is in Table A-29 and for July in Table A-30 of the Appendix. A plot of the average of calculated flows ($\bar{x}$ values from Tables A-10 and A-21) is shown in Figures 17 & 18. The end of May was quite wet and the trend of flows throughout the month of June was generally downward. The rainfalls on June 21 and 28 had little effect on the trend. In the month of July, the trend of sewer flow was upward. The precipitation had little influence on sewer flows until the storm of the 28th, but even this storm did not result in a surcharged condition. The resulting distribution of sewer flows during June and July was inadequate to test hardness as an indicator of infiltration since the plot results in a mass of points at the low-flow end of the scale and one point at a higher flow.

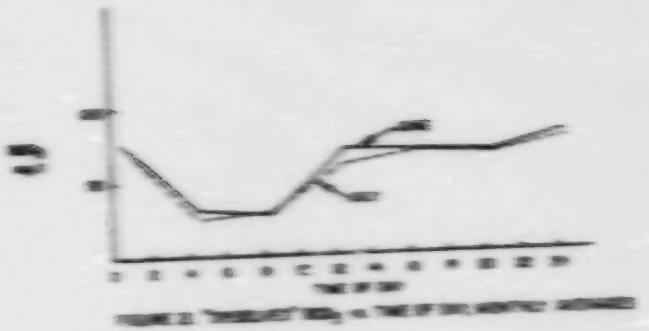
However, to illustrate the interesting relationship of alkalinity to flow, the data for alkalinity for all three months of its measurement is plotted against the sewer flow at 0400-0500 hours and is shown in Figure 19. The early morning hour was selected on the basis that it is the sampling hour least influenced by normal sewage flows. The curve was not straightened when plotted on semi-log or log-log paper.

Total and "dissolved" values of BOD_5 and COD were examined with respect to time of day to provide some indication of the limits of effectiveness of a sedimentation treatment process. Figure 20 shows the plot for total BOD_5 for the two months and Figure 21 shows the "dissolved" BOD_5. The percentage of total BOD_5 that is dissolved is shown in Figure 22 -- a remarkably consistent percentage.

The ranges of other data collected in June and July which are not detailed in tables in the Appendix are shown in Table 1.

FIGURE 10 CALCULATED FLOW vs ALKALINITY AT 0430-0500 HOURS





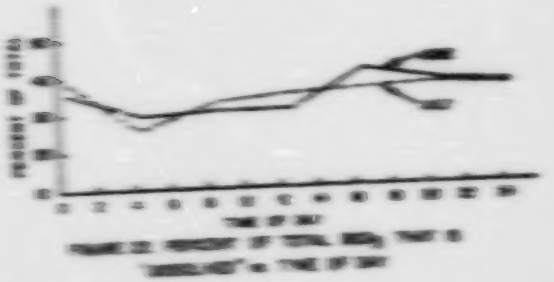


Table 1. Range of Analytical Data for months of June and July, 1971

Constituent	June		July	
	Min.	Max.	Min.	Max.
DO, mg/l	0	5.6	0.0	3.2
pH, units	6.8	7.8	6.9	7.8
Temperature, °C	25	28	27	30
Settleable solids, ml/l	0	60.0	1.0	11.0
Conductivity, umhos	566	934	607	867
Organic N, mg/l	4.9	35.0	3.2	21.0
NH_3-N,mg/l	6.1	29.1	1.7	24.5
NO_2-N, mg/l	0.005	0.11	0.001	1.19
NO_3-N, mg/l	0.21	1.95	0.05	1.53
Total P, mg/l	3.1	26.7	1.1	19.3
MBAS, mg/l	0.0	5.1	-	-

The distribution of zero-DO values was of interest in that in April 15% of all samples were zero, 31% in June, and 57% in July. However, the zero values were all associated with the lowest flows and suggested that odors associated with zero-DO wastewaters would likely not be a problem to the plant which would be operating only during high-flow conditions. The results of the chlorine demand studies are discussed in Section VII.

SECTION VI

PLANT DESCRIPTION AND COSTS

Plant Description

The whole of the Bachman treatment facility can be best described by its three components:

1. Waste lime recovery station
   a) Waste lime diversion structure
   b) Waste lime pumping station
   c) Waste lime sludge concentrator, pumps, and transfer line
2. Wastewater diversion structure
3. Treatment facility
   a) Wet well, comminutor, bar rack, and pumps
   b) Parshall flumes (three in number, one for each basin)
   c) Sludge recirculation (basins 1 and 2 only)
   d) Flocculators (preceding basins 1 and 2 only)
   e) Sedimentation basins 1, 2, and 3
   f) Tube settlers (basin 1 only)
   g) Chlorination facilities

The waste lime recovery station is located on the grounds of the Bachman Water Purification Plant (see Figure 2). The diversion structure (see Figure 23) is simply a 10'x10' x 16'10" deep (3 m x 3 m x 5.1 m internal dimensions), square-type, manhole-like structure that cuts into the 36-in (91.4-cm) cast-iron pipe (C.I.P.) waste line which conveys waste sludge and filter backwash water from the water purification plant to Bachman Creek, and accommodates the new 16-in (40.6-cm) pipe which taps into the waste line. The structure also accommodates a sluice gate at the opening of the 16-in (40.6-cm) line and a stop plate to backup flow to feed the 16-in (40.6-cm) line. Flow through the 16-in (40.6-cm) line goes by gravity to an adjacent recovery station.

The potable water treatment plant waste lime pumping station is an 8' x 12' x 22'10" deep (2.4 m x 3.7 m x 7 m internal dimensions) structure (Figure 24) into which the 16-in (40.6-cm) line from the diversion structure discharges. The gradient drops 0.17 ft (5.2 cm) in about a 12-ft (3.7-m) distance with a 56-1/4° bend in the line. The bottom of the recovery station contains two hoppers, each of which accommodates the suction of a pump. Two vertical diffusion vane pumps are located on the top surface of the structure. Both are 5-HP (3.73-kW), 700-gpm (44.2-lps) units that operate automatically on a float gage. One is variable speed, the other serves as standby. Delivery is to a 16-in (40.6-cm) C.I.P. which conveys the sludge to the concentrator approximately 154 ft (47 m) away. The line contains two bends, one 11-1/4°, the other 22-1/2°, plus two 90° bends at the pump pad, one directing the line down into the ground

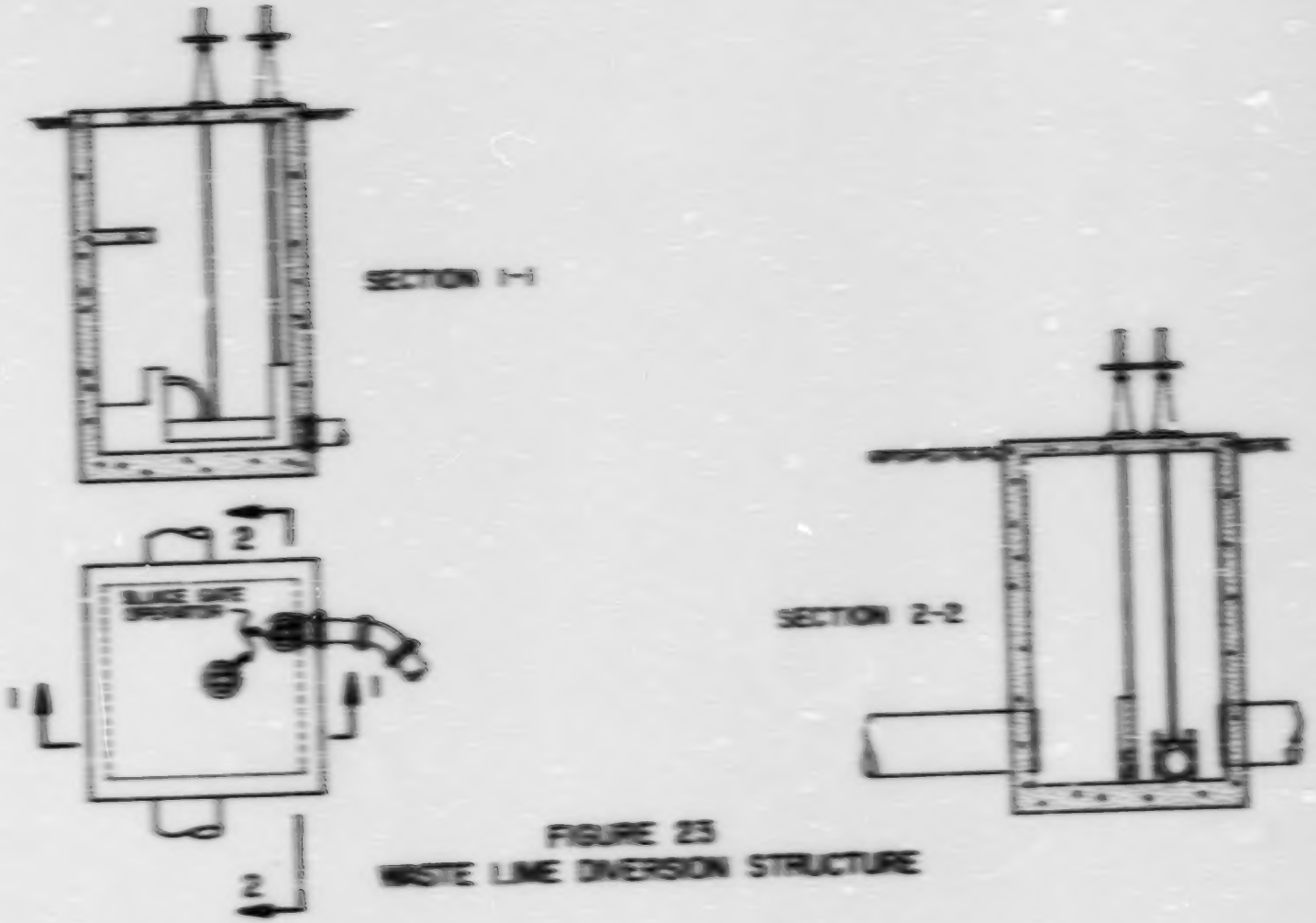


FIGURE 23
WASTE LIME DIVERSION STRUCTURE

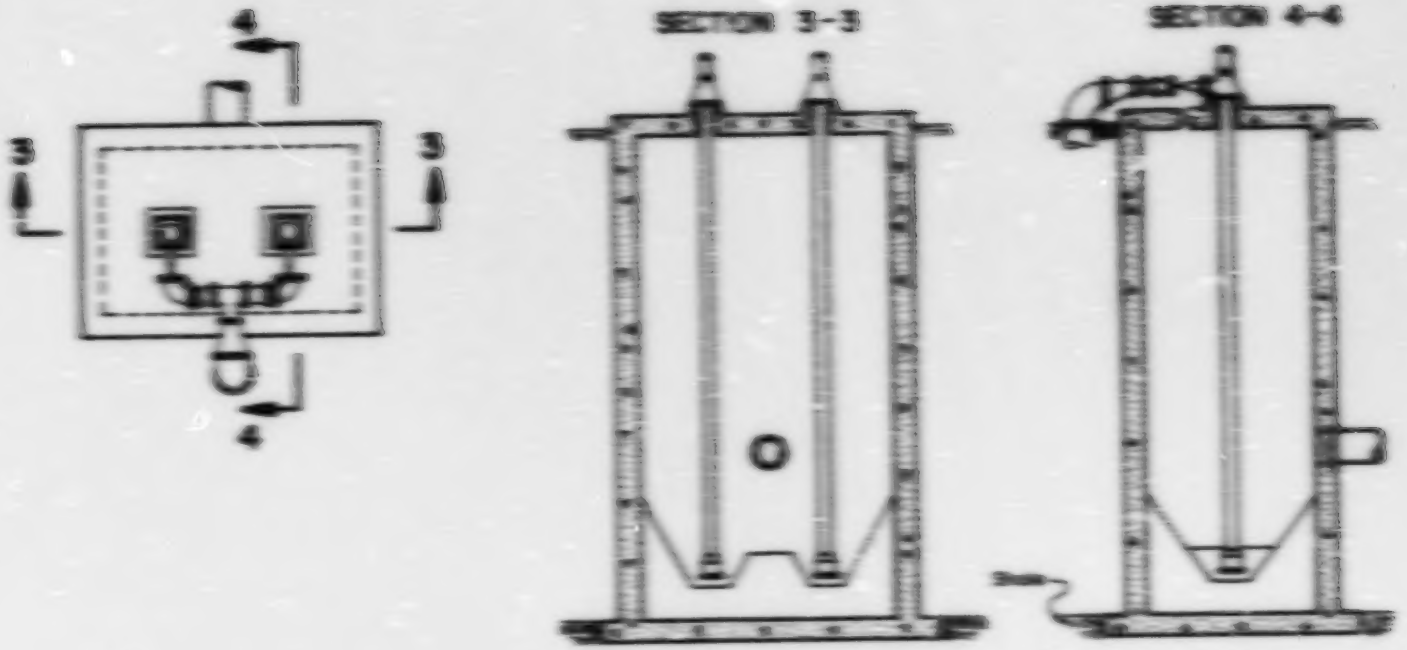


FIGURE 24.--WASTE LIME PUMPING STATION

and the other directing it horizontally and parallel to the ground surface plus two more 90° at the concentrator. The overall difference in elevation between the outlet of the pump on the pump pad and the inlet to the concentrator is about 4 ft (1.2 m).

The waste lime sludge concentrator (Figure 25) is a 25,000-gal (98,400-liter) conical-frustum unit. The waste sludge enters peripherally and tangentially behind a 6-ft (1.8-m) deep peripheral baffle and settles by gravity into a hopper. The 30-ft (9.1-m) surface diameter provides an overflow rate of 1414 gpd per sq ft (40 lpm/m^2) at a design flow of 700 gpm (44.2 lps). Clarified water passes over an inner weir to Bachman Branch. The bottom diameter of the frustum is 4.5 ft (1.37 m) and the depth is 13 ft (3.96 m). The concentrated sludge in the bottom is kept in a slurry by a 10-HP (7.5-kW) mixer and is pumped out and into an 8-in (20.3-cm) C.I.P. sludge transfer line to the treatment facility by two 10-HP (7.5-kW) Gorman-Rupp sludge pumps. The transfer line is equipped with taps to accommodate a clean-out pig. Its grade drops about 9.5 ft (2.9 m) from the concentrator to the treatment facility, a distance of about 1000 ft (305 M). There is also a drop of about 6 ft (1.8 m) from the pump to the line at the pump pad.

The wastewater diversion structure is constructed right on the 60-in (152-cm) reinforced concrete pipe (R.C.P.) interceptor (see Figure 2). Its exterior dimensions are 25' 1/2" x 12'4" x 32'11" deep (7.63 m x 3.76 m x 10.03 m deep). The plan section is 5-sided (see Figure 26). The section of the 60-in (152-cm) line within the diversion structure was removed and the outlet pipe opening fitted with a 78-in (198-cm) sluice gate. Provision is made for a future 60-in (152-cm) line into the diversion structure. A 48-in (122-cm) diameter R.C.P. goes from the diversion structure to the wet well of the treatment facility, and this line also has a sluice gate, a 48-in (122-cm) unit in the diversion structure. The inlet to the entrance chamber for the 48-in (122-cm) line is protected by a vertical 3-in (7.6 cm) bar rack and the chamber also contains a 2-in (5-cm) chlorine feed line. When the wastewater level in the diversion structure reaches a predetermined elevation, the 48-in (122-cm) sluice gate automatically opens admitting water to the line to the treatment facility. Flow is by gravity. The difference in elevation is 1.45 ft (44.2 cm) in a distance of about 90 ft (27.4 m) with a gentle bend of about 52° in the line.

In the wet well approach, flow can pass through either a Worthington 3-hp (2.4-kW) comminutor or by-pass the comminutor through a 1-in (2.54-cm) bar rack. When the wastewater level in the wet well reaches minimum pump submergence, both the comminutor and a first pump are automatically activated. The wastewater level in the diversion structure, however, controls the speed of pumping. When the capacity of one pump is exceeded, a second pump is activated automatically. Three pumps are located on the top of the wet-well structure, and

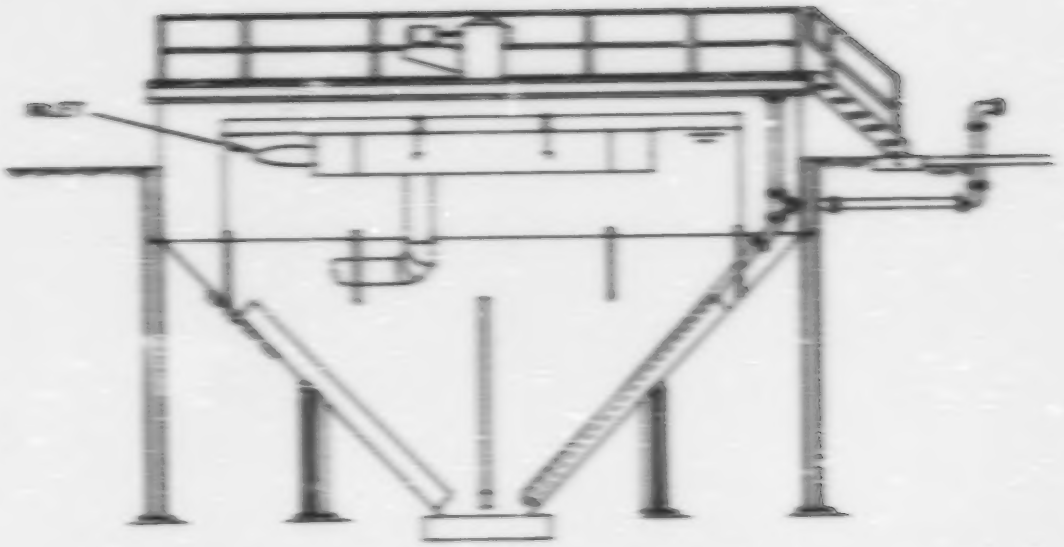
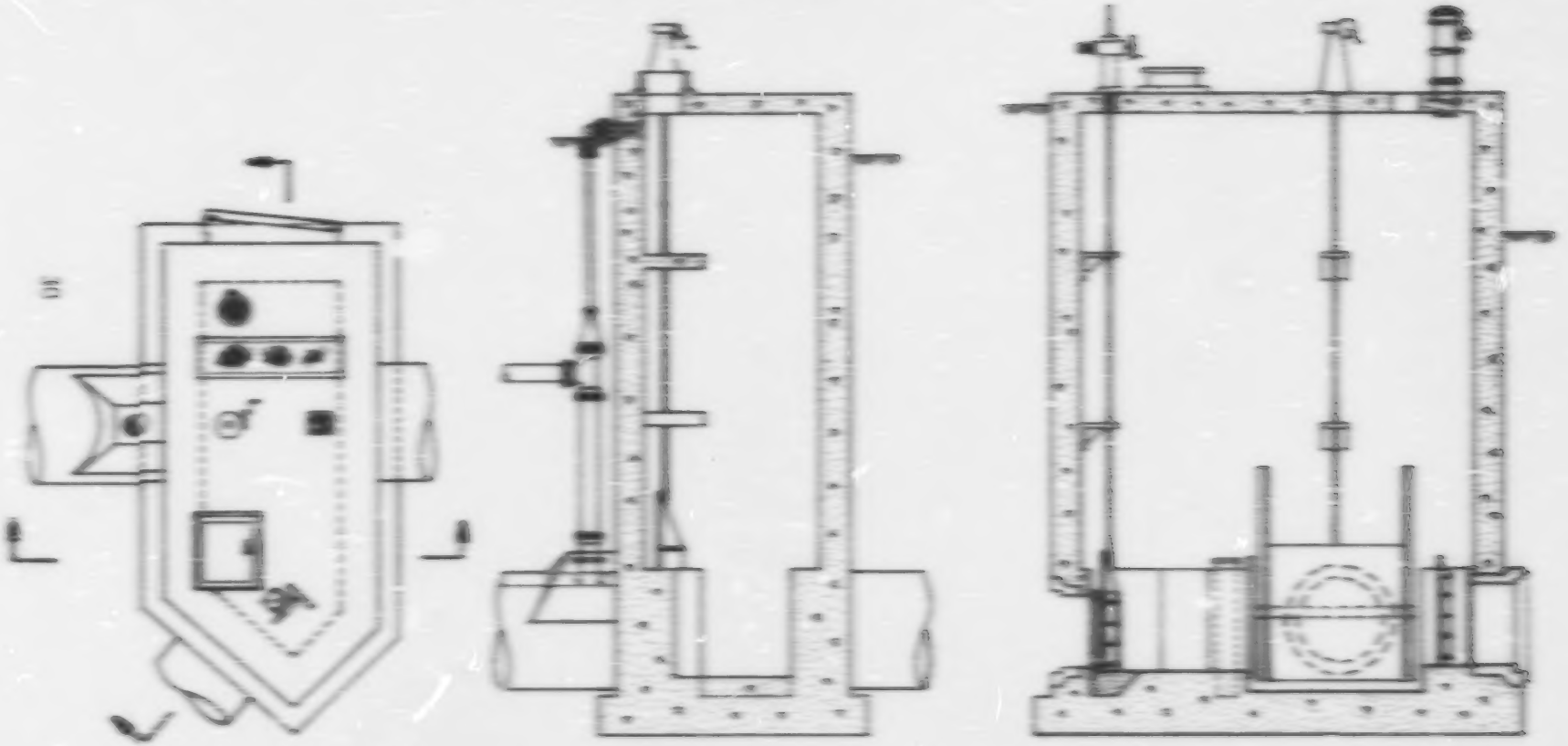


FIGURE 25- WASTE LIME SLUDGE CONCENTRATOR

FIGURE 15-WASTEWATER DIVERSION STRUCTURE



space is provided for a future fourth pump.

Two pumps are provided with magnetic couplings and external thrust bearings. The third pump is constant speed. The constant speed pump motor is 125 hp (93.3 kW), 1200 rpm, vertical, hollow shaft, air cooled with full voltage starting. The two variable speed pump motors are 125 hp (93.3 kW), 1200 rpm, air cooled, solid shaft units. One variable speed unit serves as standby. The floor of the wet well slopes toward a sump, and during cleanup activities following plant operation a sump pump delivers the flow to a common waste line which goes to the interceptor.

Flow from the main pumps of the facility is directed to a flume which feeds three Parshall flumes. Three Parshall flumes adjacently located each serve one of the three sedimentation basins (see Figure 27). Manually operated gates precede flumes 1 and 2, a stop gate precedes flume 3. Each flume is provided with a stilling well, a water flushing line, and flow recording equipment. Flows from flumes 1 and 2 go to flocculation basins, flow from flume 3 goes directly to sedimentation basin 3.

Waste sludge from sedimentation basins 1 and 2 is recirculated to the respective Parshall flumes by two Chicago Pump 500 gpm (32.8 lps), 2-HP (1.5-kW) centrifugal pumps with constant speed motors. Waste sludge recirculation is not provided for basin 3. Waste flow sludge passes through propeller meters and into flumes 1 and 2. The discharge line of each recirculating pump is provided with a magnetic flowmeter and motor operated valve. A branch off of the suction line is provided for sludge wasting. The sludge line from basin 3 is provided with a motor-operated, timer-controlled valve and goes to the common waste line and then to the interceptor.

The two flocculation basins have baffled entries and exits provided by double rows of red wood two-by-eights (2 in x 8 in or 5 cm x 20 cm) vertically mounted with 1-in (2.5-cm) separations, the two rows being separated by a space of 4 in (10 cm). Each basin is equipped with two Walker Process five-speed flocculators driven by 10-HP (7.5-kW) motors. At a design flow of 9.3 MGD (407 lps) per basin, flocculation detention time is 10 minutes. The flocculators can achieve a velocity gradient of 200 sec^{-1}.

Flow into the sedimentation basins is through a slotted influent distribution flume. Each of the three sedimentation basins contains two bays although there are no partitions between the bays. The first bay (in a flow direction -- see Figure 27) of each basin is equipped with Walker Process sludge collecting equipment driven by 0.75-HP (0.56-kW) motors. The basins are designed for an overflow rate of 1720 gpd/ft^2 (48.9 lpm/m^2). The overflow rate on basin 1 on the area preceding the tube settlers is 2160 gpd/ft^2 (49.2 lpm/m^2). At the design flow of 9.33 MGD (407 lps) and a 10.5-ft (3.2-m) depth,

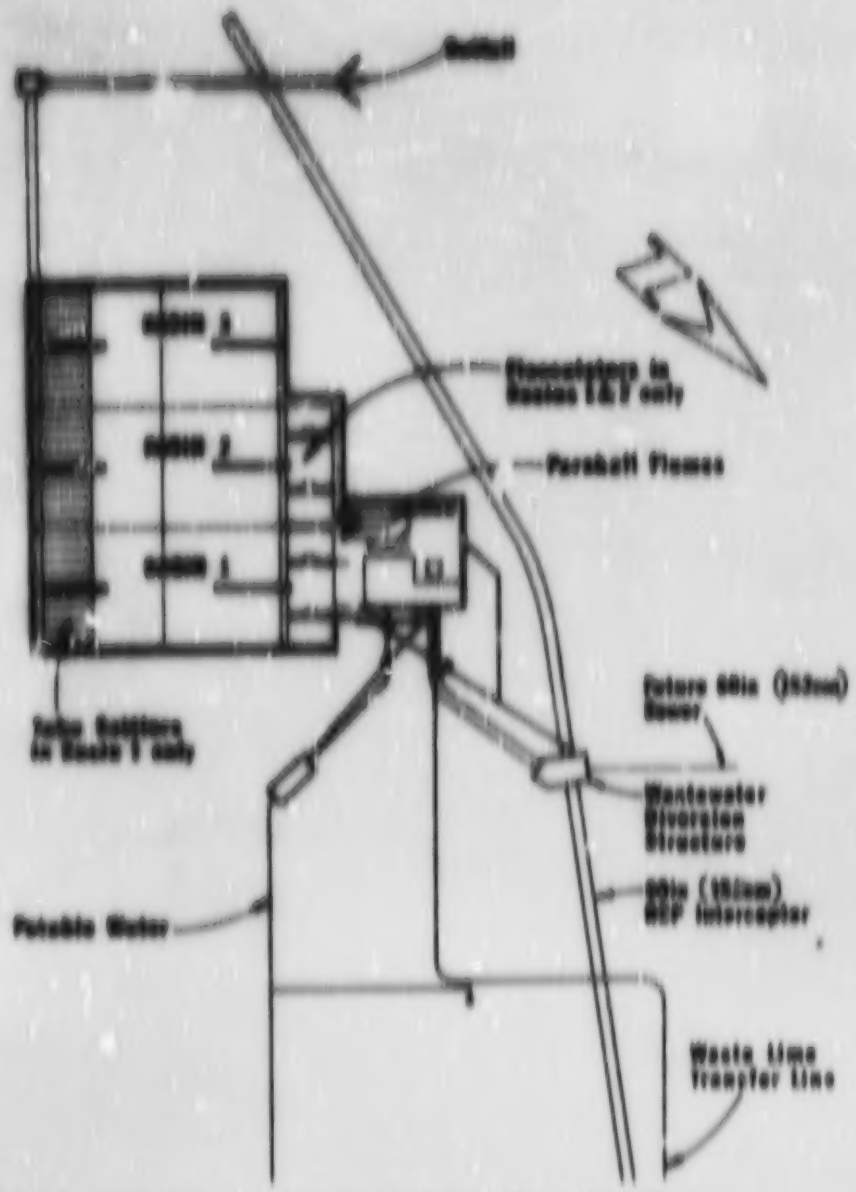


FIGURE 27- BACHMAN TREATMENT FACILITY LAYOUT

detention time is 66 minutes. Weir overflow rates at the design flow are 22,000 gpd/ft (190 lpm/m). No skimming is provided. The basins are dewatered by a Gorman-Rupp 10-HP (7.46-kW) pump which discharges to the common waste sludge line. Sludge collecting equipment can be added to each of the second bays should it prove needed. Weep holes are provided in the common non-structural walls between basins; hence, no one basin can be operated without all being filled and without some consequent outflow from the non-operating basins.

Basin 1 is equipped with tube settlers designed at an overflow rate of 6 gpm/ft^2 (244.3 lpm/m^2). They are positioned immediately under the effluent launders (see Figure 27).

The chlorine room houses one 2000 lb/day (909 kg/day) chlorinator and a wall mounted three-unit solution distribution panel. Provision is made for an additional chlorinator. Chlorine cylinder storage is in an open area adjacent to the chlorine room. Six 1-ton cylinders can be connected on a header to minimize the withdrawal rate from a single cylinder. The chlorine solution is distributed across the width of each sedimentation basin at mid-basin (between bays) thus providing a theoretical thirty-minute contact period. A chlorine evaporator was added later.

Plant influent is monitored by a Hach Co. C A falling stream turbidimeter. The readout is located in the laboratory. Automatic flow-regulated composite sampling equipment, Utility Control Corporation, discharges to refrigerated containers also located in the laboratory. Influent is sampled proportionally to flow through basin 1, and effluent is sampled from each of the three basins according to the flow through each.

An aerial view of the completed treatment facility is shown in Figure 28. Schematic representations are shown in Figures 29 and 30.

Plant Costs

Plant costs are separated into construction and operation. Original construction cost estimates included:

Sedimentation basins	$ 330,000
Control building	111,000
Pumping station	190,000
Diversion structure	26,000
Yard work	79,000
Lime feed facilities	35,000
Heating and ventilation	4,000
Electrical	100,000
Instrumentation	50,000
Engineering and contingencies	139,000
Total construction cost	$1,064,000

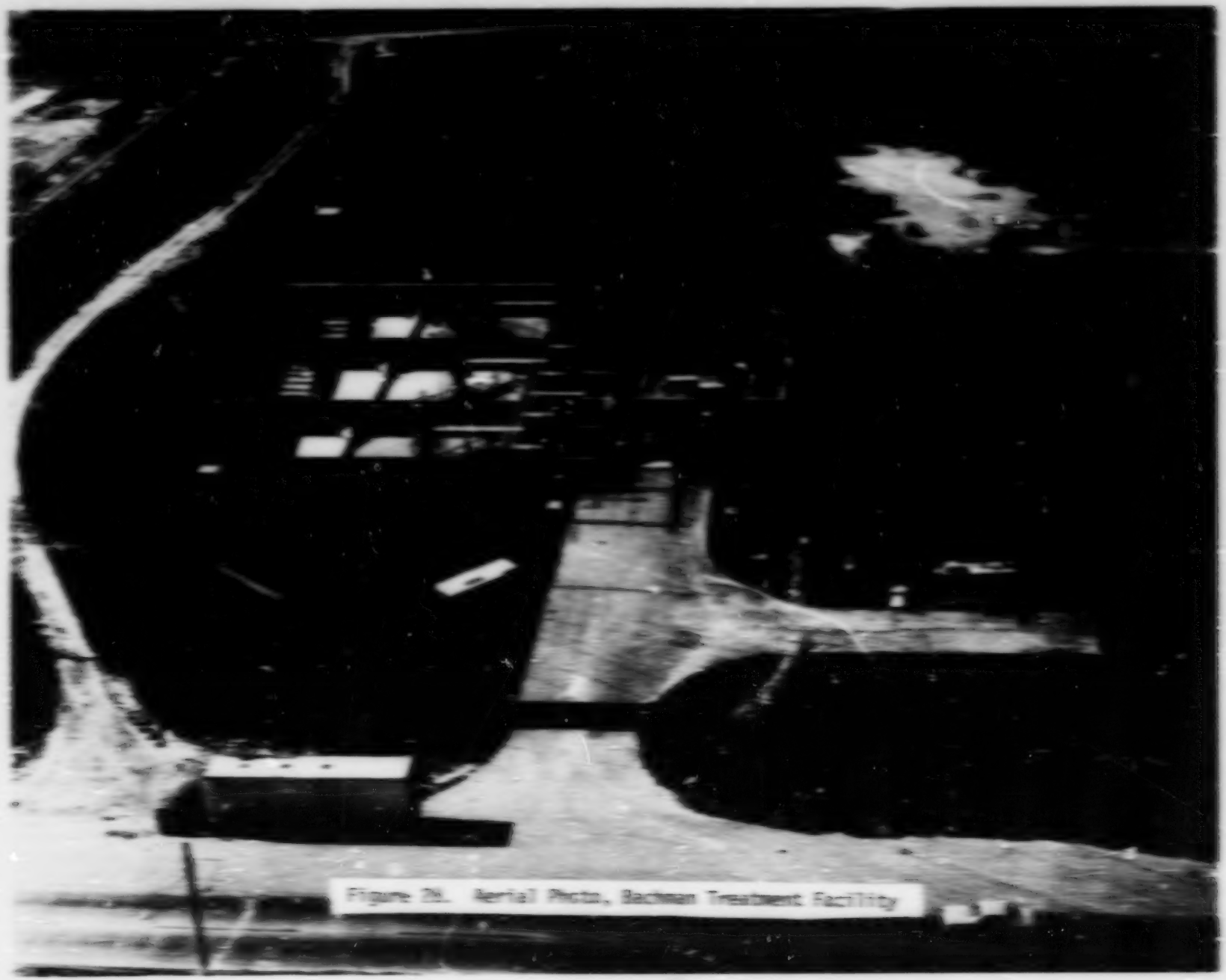
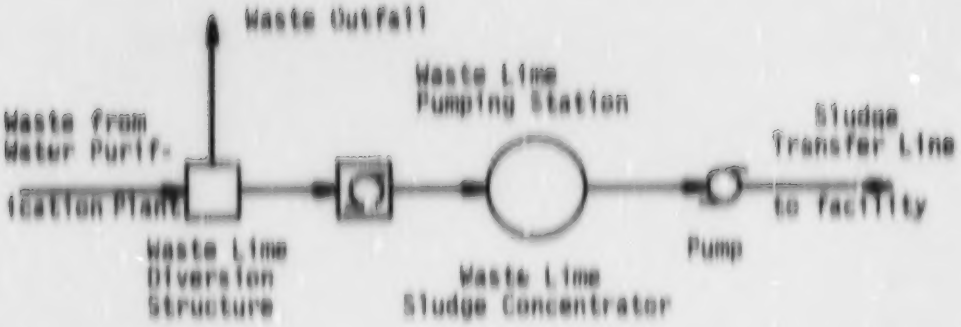
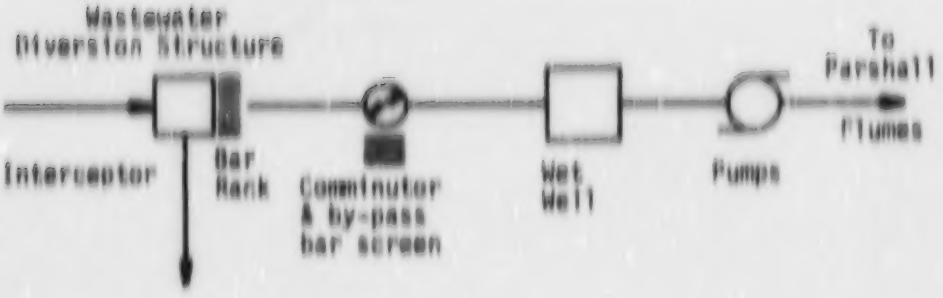


Figure 26. Aerial Photo, Bachman Treatment Facility



Waste Lime Recovery Station



Diversion Structure & Head Works

Figure 29. Schematic representation of Waste Lime Recovery Station, Diversion Structure, and Facility Head Works.

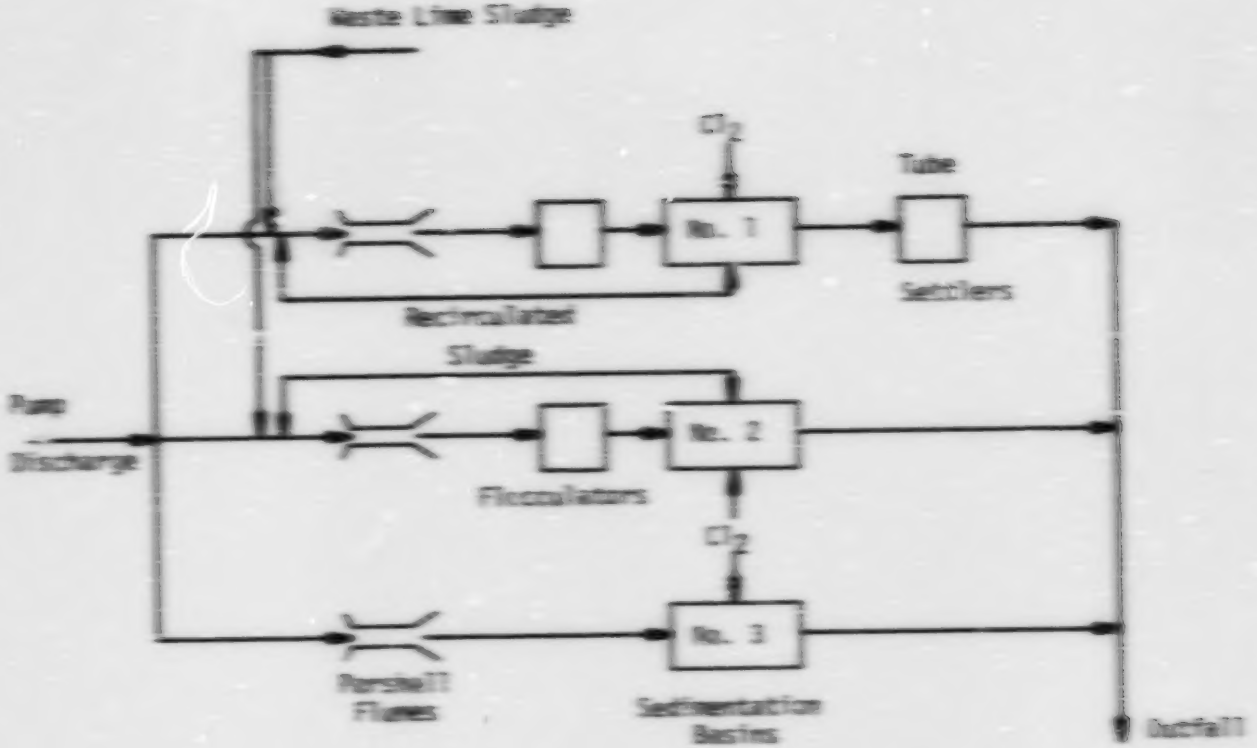


Figure 38. Schematic representation of treatment facility.

The low bid that garnered the contract was for $1,320,500.

Operating costs were determined for July 1973 and were calculated at:

Personnel	$ 415.34/day
Power (27 MGD)	104.15/day
Chlorine	460.36/day
Maintenance Supplies	30.00/day
Depreciation	344.00/day
	$1,423.85/day

Operation of the facility in the period of time following this report utilized polymers. The optimal feed of polymer has been indicated to be 6 mg/l. At this rate and at $2.20/lb ($4.86/kg), polymer costs and resulting total operating costs are:

Polymers	$2,476.98/day
TOTAL DAILY COST	$3,900.83
Cost per million gallons (3785 M^3)	$ 144.48

SECTION VII

BENCH-SCALE INVESTIGATIONS

This section summarizes a number of laboratory investigations which were undertaken aimed at determining how effective the proposed treatments might be and, if necessary, how the treatments might be improved. When these studies were undertaken, there were no guidelines available to establish criteria of performance. Hence, we tentatively adopted goals of 20 mg/l for both suspended solids and BOD_5 and 1 mg/l after one hour of contact for chlorine residual.

Chlorine demand tests using recommended procedure 4a of Standard Methods (2) were run on eight samples of wastewater collected from the diversion structure in the month of July 1971. The strongest demand -- which was exhibited by three of the eight samples -- indicated that about 12 mg/l would be needed to achieve a 1 mg/l residual after one hour of contact. Calculations thus showed that a least 2800 lb/day chlorinator capacity would be needed some of the time at design flows and this without the addition of waste lime sludges which would sometimes contain powdered activated carbon. As described in Section VI, the facility was provided with only 2000 lb/day chlorination capacity. These observations plus subsequent operating difficulty with the chlorination equipment (froze at higher rates of flow) resulted in purchase of additional equipment mentioned in Section VI.

One of the difficulties which was readily apparent from the outset but never answered satisfactorily was how to conveniently control the concentration of waste lime sludge during facility operation. A number of samples (sixty-three) of waste lime sludge were collected from the water purification plant over a 16-month period and analyzed for suspended, settleable, and dissolved solids. The results varied considerably as one might expect:

ANALYSIS	MAX	MIN	AVG
Suspended solids, mg/l	10,360	215	3,361
Settleable solids, ml/l	100	1.6	30
Dissolved solids, mg/l	292	138	182
Volume of waste/day, MG	5.19	0.086	1.085
Volume of waste/sec, liters	227	3.8	82.6

A plot of suspended vs. settleable solids revealed a relationship (see Figure 31) that could later be checked out in plant operation as a possible operational tool. An idea of what the sludge consists of -- besides mud -- can be gleaned from the water plant's use of chemicals which, for the month of June 1971, was:

	lbs/10^6 gal	mg/l
Lime (CaO)	500	60
$Fe_2(SO_4)_3$	155	18.6
Carbon	35	4.2

FIGURE 31

SUSPENDED vs. SETTLEABLE SOLIDS, WATER TREATMENT PLANT WASTE LIME SLUDGE

Average daily treatment for this month was 65 million gallons (246 x 10^6 liters).

The storm of July 28, 1971 caused a peak sewer flow of approximately 27.2 MGD (1191 lps) at 1500 hours which compares to a normally expected dry-weather flow for that month of about 5.5-6.0 MGD (241-263 lps), and it was at this peak flow that the first sample was taken for jar testing.

A sample of water purification plant waste sludge was collected which assayed 17,000 mg/l suspended solids. Aliquots of sewage from the peak-flow sample were mixed with this water purification plant waste sludge and jar tested at 100, 300, 500, 600, and 700 mg/l calculated concentrations of waste sludge. Also, one sample of tap water was included to which was added a calculated 600 mg of waste sludge per liter. After 60 minutes of settling, turbidity and pH of the supernatant was determined. (The water treatment plant laboratory was not as yet equipped to run suspended solids--for which samples would have to be transported to the wastewater labs. Hence, it was decided to utilize turbidity as a parameter of treatment effectiveness.) The pH meter was subsequently found to be defective, but the turbidities of the sample supernates ranged from 20-120 JTU, varying directly with the concentration of sludge added (the greater the concentration of waste sludge added, the greater was the resulting turbidity). The turbidity of the tap water sample was 410 JTU--decidedly higher than the sewage samples. A second set of samples was tested with dosages of water purification plant waste sludges in the 400-700 mg/l range and the observation of increased turbidity with increased dosage was again observed. The pH values of the second series ranged from 7.4 to 7.6. The pH of the peak-flow sample was 7.3 indicating the possibility of some--but very little--unspent lime in the waste sludge.

The first tests utilizing chlorine demand and turbidity as parameters had suggested the possibility of inadequacy in treatment. Additional jar tests using the suspended solids procedure was desired but the water purification plant was shut down for major repairs on October 25, 1971. In the meantime, it was decided to proceed with the jar testing of coagulants. (Prior to the water plant shut down, the Bachman Facility was actually placed in operation on three different occasions in the month of October 1971--which is reported in Section VIII, Plant Operation.)

A second series of jar tests were conducted to test the effectiveness of varied doses of three coagulants. Samples were collected from the diversion structure at 8 AM when the sewage was relatively organically dilute--since this was most likely to represent the organic quality of flow under surcharge conditions. Ferric chloride, ferric sulfate, and alum (all without lime) were screened at concentrations of 0-20 mg/l as $FeCl_3$, $Fe_2(SO_4)_3$, and $Al_2(SO_4)_3$.

All three at 20 mg/l concentrations proved capable of reducing the suspended solids to 20 mg/l; however, the untreated control among these samples contained suspended solids concentrations of only 40-60 mg/l.

Higher concentrations--50 to 60 mg/l--of the same three coagulants were tried both with and without supplemental lime. All tests showed reductions of suspended solids to 10 mg/l regardless of the initial suspended solids concentration which was 30 or 60 mg/l, and BOD_5 was reduced to the range 20 to 30 mg/l from initial values of 50 to 95 mg/l, respectively.

Although the Bachman Water Purification Plant was out of operation, it was eventually realized that water plant sludge could be obtained for test purposes from another of the city's water treatment plants--the Elm Fork Water Purification Plant. This plant is located about 20 miles (32 km) north of the Bachman Plant and treats water from the same waterway utilizing the same chemicals. Hence, samples of the Elm Fork plant sludges were obtained and utilized in further testing. In these tests, addition of water plant waste sludges of 100-300 mg/l reduced the suspended solids content from an initial value of 40-60 mg/l down to 20 mg/l, but higher concentrations of waste sludge (600-900 mg/l) resulted in increased suspended solids.

It was also considered desirable to observe the performance of a combination of small amounts of coagulant plus water plant waste sludge on wastewater. By the time these jar tests were conducted, the water plant laboratory was equipped to run BOD's. Alum was used as the coagulant. A fixed 5 mg/l concentration of alum was tested with varying amounts (100-600 mg/l) of water plant waste sludge. The 400-600 mg/l samples yielded suspended solids and BOD_5 of 20 and 25 mg/l respectively from initial concentrations of 60 and 35 mg/l respectively. The samples with lesser concentrations of waste sludge yielded poorer quality supernatant. Another test run at a fixed alum concentration of 10 mg/l plus the same amounts of water plant waste sludges yielded the same final suspended solids value--20 mg/l regardless of the water plant sludge dose. BOD_5 values were similarly reduced to 50-55 mg/l. Initial levels of suspended solids and BOD_5 of the wastewater were 80 and 105 respectively. A sample of sewage was then collected at 1400 hours when organic content is normally high which yielded a suspended solids of 80 mg/l and BOD_5 of 170 mg/l. A fixed 15 mg/l concentration of alum was used with varying water plant sludge concentrations and this test showed an increasing capability for removal of both suspended solids and BOD_5 with higher sludge doses. However, the maximum reduction observed was only to 60 mg/l for suspended solids and 120 mg/l for BOD_5. The same procedure was rerun on a morning sample collected when the organic content is normally low. The results for suspended solids were a reduction from an initial value of 60 mg/l to a final value of 40 mg/l in all jars. BOD_5, however, was reduced most by the highest

sludge concentration (600 mg/l) sample--to 22 mg/l from an initial value of 80 mg/l.

The results of the jar testing were thus quite mixed. In general, however, the tests indicated that water plant waste sludge if used alone would give best results at the lower concentrations of 100-300 mg/l. If used with supplemental coagulants, best results would accompany higher waste sludge concentrations--400-600 mg/l. Also, better quality certainly results from increased coagulant usage. The use of metal salts was tucked away as only an item of last resort in the operation of the facility. The reason prompting this decision was that facility sludges would all be ultimately deposited in the anaerobic digestion tanks of the city's sewage treatment facilities, and digestion space was reported to be strained. For further discussion, see Section VIII.

A series of jar tests were also performed on water treatment plant waste sludge per se. Polymers were used in these studies, Hercofloc low, medium, and high antonic and cationic types. These tests were undertaken to explore the possibility of enhancing the activity of the water plant waste sludges. The concept would be to add the polymers at the inlet of the water plant sludge diversion structure, after which they would settle out with the sludges in the concentrator, flow to the Bachman Facility and thence be utilized. All polymers exhibited good results at concentrations down to 1 mg/l with the edge, perhaps, going to the medium cationics. This concept, however, was not implemented.

SECTION VIII

FACILITY OPERATION

The material contained in this section is presented chronologically and in three parts. The first part presents data acquired when the facility was operating on high sewer flows that occurred during or following heavy precipitation (Runs 1-8) as it was designed to do. The second part presents data that was acquired when the facility was operating on artificially diluted sewer flows (Runs 9-19). It was necessary to resort to adding water (stream water and/or potable water from a fire hydrant) to the sewer in order to achieve sufficient flow to operate the facility because a combination of dry weather and a highly effective conterminous infiltration control program resulted in insufficient flow for operation. Lastly, the third part presents data obtained when polymer solutions were fed into the Parshall flumes (Runs 20-24). The sum total of the experiences of the first two parts indicated that the facility could not achieve the quality required by the State for discharge, and additional treatment was necessary. Hence, polymer applications were tried.

Part 1 - Naturally Occurring Flows

Runs 1,2, and 3 were made before the facility was completed and before it had been officially turned over to the City by the contractor. The purpose of these three runs was primarily for shakedown. Data acquired were necessarily incomplete. Nevertheless, because of the scarcity of runs on naturally occurring sewer flows, such data as were acquired are presented in Tables 2, 3, and 4.

Run 1 lasted only three hours, and of this time, discharge occurred for only 1/2 hour. During the filling operation, the flows through the three Parshall flumes were summed and calibrated against the rise in the basins. When the basins were filled, basin 3 was taken out of operation in order to allow a higher flow rate through basins 1 and 2. The sewer flow rapidly dropped off to an insufficient amount to operate the plant after only a 30-minute period of discharge. Prior to plant shut down, grab samples of the influent and two effluents were obtained and subjected to the limited analyses shown in Table 2.

After operation, the facility drained by gravity into the East Bank interceptor through the common waste line until the water level dropped to the elevation of the recirculated sludge collection header, then the remaining wastewater was removed by the 200 gpm (12.6 lps) dewatering pump. The plant was washed down by the contractor. All of the equipment that could be checked had worked well.

Heavy precipitation allowed additional shakedown runs on October 19 and 20, 1971. Discharge from the facility commenced at 1500 hours

Table 2. Run No. 1, October 4, 1971

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	5.75/274	5.75/274
Waste Lime Sludge Flow, MGD/lps	0.5/22	0.5/22
Recirculated Sludge Flow, MGD/lps	0.75/33	0.75/33
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	1239 35	1239 35
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	4.1 167	-

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	60	<15	<15
COD, mg/l	257	110	90
Suspended Solids, mg/l	234	82	60
Settleable Solids, ml/l	-	0.0	0.0
pH, units	-	7.7	8.1

Performance, Percent Removal:		
BOD_5	>75	>75
COD	57	65
Suspended Solids	65	79

Table 3. Run No. 2, October 19, 1971

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.75/164	2.75/120	5.0/219
Waste Lime Sludge Flow, MGD/lps	0.5/22	0.5/22	-
Recirculated Sludge Flow, MGD/lps	0.75/33	0.75/33	-
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	$\frac{643}{24}$	$\frac{645}{18}$	$\frac{992}{26}$
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	$\frac{2.8}{114}$	-	-

Quality:	Influent	Effluent Basin 1	Effluent Basin 2	Effluent Basin 3
BOD_5, mg/l	30	<12	<12	17
COD, mg/l	140	80	80	120
Sus. Solids, mg/l	72	22	24	29
Sett. Solids, ml/l	0.0	0.0	0.0	0.0
pH, units	7.4	7.2	7.1	7.4
Cl$_2$ Residual, mg/l	-	2.3	2.3	1.6
Alk., mg/l	237	177	180	196
Cl^- (as NaCl), mg/l	46	52	53	52
Hardness, mg/l	332	292	302	307

Performance, Percent Removal:			
BOD_5	>60	>60	43
COD	43	43	14
Sus. Solids	69	67	60

Table 4. Run No. 3, October 20, 1971

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	2.75/120	2.5/110	4.0/175
Waste Lime Flow, MGD/lps	0.5/22	0.5/22	-
Recirculated Flow, MGD/lps	0.75/33	0.75/33	-
Overflow Rate, gpd/ft²	644	595	793
lpm/m²	18	17	22
Tube Settler Rate, gpm/ft²	2.1	-	-
lpm/m²	86		

Quality:	Influent	Effluent Basin 1	Basin 2	Basin 3
BOD_5, mg/l	48	<12	<12	14
COD, mg/l	180	80	100	140
Sus. Solids, mg/l	96	25	6	29
Sett. Solids, ml/l	4.0	0.0	0.0	0.0
pH, units	7.3	7.5	7.4	7.1
Cl_2 Residual, mg/l	-	2.9	3.2	2.3
Alk.,mg/l	236	209	199	192
Cl^-(as NaCl), mg/l	49	64	67	66
Hardness, mg/l	339	326	336	328

Performance, Percent Removal:			
BOD_5	>75	>75	71
COD	56	44	22
Sus. Solids	74	95	70

but was terminated at 1615 hours. Grab samples of the influent and three effluents were obtained and subjected to the analyses shown in Table 3. The wastewater diversion structure gate value, which controls wastewater flow to the facility, could not be closed because of a misaligned value shaft. Consequently, the wet well could not be dewatered. However, the basins were allowed to drain.

On the morning of October 20, 1971, the depth of flow in the interceptor was still sufficiently high to permit facility operation. An effluent began discharging at 1020 hours and continued until 1610 hours. Grab samples of the influent and three effluents were obtained and subjected to the analyses shown in Table 4.

As most comforting observation of these early shakedown runs was that the only odor emanating from the plant was a slight chlorinous odor, and that even after standing overnight, there was no detectable sewage odor

After the diversion structure gate value was repaired and the wet well drained it was found that a large amount of grit had accumulated in the wet well which had to be bucketed out by hand. Further, each bucket had to be toted up 36 steps.

The take-over date (December 20, 1971) of the facility by the City from the contractor terminated a very wet period and initiated a very dry period. The plant lay idle until the following October 1972 when it was decided to use it to process waste lime sludges from the water treatment plant. Attempts to fill the basins with these wastes revealed severe leakage from the basins, leakage equaling the 1 MGD (43.8 lps) input when the water surface was still two feet (61 cm) below the effluent launders. The plant was drained, but before repairs could be made, heavy rains enabled another operation of the facility.

In thisoperation, Run 4, the plant was set to operate on its automatic controls. When the wastewater level in the diversion structure reached the predetermined 4.25 feet (1.3 m) on November 1, 1972 at 0915 hours, the gate in the diversion structure opened and the comminutor commenced operation. At 0920 hours the No. 1 variable speed pump commenced operation and the basins began filling. At 1245 hours, three things occurred: the comminutor jammed, an effluent started being produced, and the sewer flow peaked and started dropping off steadily thereafter -- the run terminating at 1500 hours.

Treatments provided were limited to sedimentation and chlorination. The evaluation protocol which was being followed and which had been approved by the contracting agency called first for comparative operations of the three basins without any chemical addition (other than disinfectant).

Sampling for Run 4 utilized both grab and composite samples. The problems with the proportional automatic composite sampling equipment -- stoppages for unknown periods of time, and blown connections which strewed sewage over the laboratory -- were such as to disenchant the staff from utilizing this equipment anymore. A grab sample was considered more reliable under these circumstances since one knows at the very least the time that it is taken.

Table 5 shows the results of influent grab samples taken at 1000, 1100, 1200, and 1400 hours. These samples were taken to observe how some influent wastewater characteristics behaved with respect to the duration of the high sewer flow, and to determine how much the chlorine demand of the raw wastewater fluctuated because the operators were experiencing difficulty in maintaining a specific chlorine residual. As can be seen from the 1400-hour sample, substantial variation does occur. Note too that this highest demand occurred along with a markedly lower settleable solids content.

Results of both 1500-hour grab samples and the "composite" samples for this influent and three effluents are presented in Table 6. The composite samples were analyzed only for BOD_5, total suspended solids, and turbidity. The remaining analyses were performed on the grab samples.

While the plant was in operation, a visual inspection at 1300 hours of the three effluents indicated that the effluent from basin 1 had the greatest clarity. Indeed, the turbidity results of Table 6 confirm this observation. The remaining data on the composite samples are such as to cast doubt on the analytical procedures. However, laboratory personnel that performed these analyses had considerable experience and it is believed that the results are more indicative of the sampling problems. The low suspended solids value for the influent, for example, could be due to removal by material that plugged the sampling lines.

During the operation it was observed that the restriction to flow imposed on basins 1 and 2 by the baffles of the flocculation basins was considerable, and that throttling of the flow through basin 3 would be essential for comparative basin performance observations at similar hydraulic loadings. This was to prove an exasperating task with only a stop gate available to throttle that flow.

The Bachman Treatment Facility then was idle for several months while repairs were in progress. During this interval (in March 1973) the Texas Water Quality Board (TWQB) specified tentative criteria and operating conditions for the facility. These are as follows:

Table 5. Influent Sample Analysis, Run No. 4

Type of Samples: Single, grab

	Time of Sampling			
	1000	1100	1200	1400
Flow, MGD/ips	8.0	11.4	14.5	11.3
Sett. Solids, ml/l	0.6	7.5	7.5	1.0
pH, units	7.4	7.2	7.1	7.1
Alkalinity, mg/l	187	184	170	182
Cl^-(as NaCl), mg/l	49	49	51	51
Hardness, mg/l	286	270	285	288
D.O., mg/l	2.7	3.3	5.3	5.4
Temp., °C	24	23	24	24
Chlorine Demand, mg/l	9.1	8.5	8.5	14

Table 6. Run No. 4, November 1, 1972

Hydraulic:		Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps		4.0/175	3.75/164	4.0/175
Overflow Rate,	gpd/ft²	792	743	792
	lpm/m²	32	31	32
Tube Settler Rate,	gpm/ft²	2.6	-	-
	lpm/m²	106		

Quality:	Influent	Effluent Basin 1	Basin 2	Basin 3
BOD_5, mg/l*	76	22	16	6
Sus. Solids, mg/l*	10	6	4	20
Sett. Solids, ml/l	3	0	0	0
pH, units	7.3	7.2	7.4	7.4
Cl₂ Residual, mg/l	-	1.3	2.5	0.5
Alk., mg/l	187	167	168	164
Cl^- (as NaCl), mg/l	54	55	56	56
Hardness, mg/l	297	296	294	292
Turbidity, JTU*	80	65	75	130
D.O., mg/l	5.7	4.6	4.5	4.8
Temp., °C	24	23	23	23

Performance, Percent Removal:			
BOD_5	71	79	92
Sus. Solids	40	60	Increase

* Composite sample values

	Monthly Average	24-Hour Composite	Individual Sample
		(Not to exceed)	
BOD_5, mg/l	-	40	40
TSS, mg/l	40	45	50
Sett. Solids, ml/l	5	6	7
Disinfection	Not less than 1 mg/l chlorine residual after at least 20 minutes exposure.		
Flow	1) Not to exceed an average of 3 MGD (131 lps) 2) Not to exceed a maximum of 27 MGD (1183 lps)		

Heavy rainfall occurred in April 1973 and a level in the sewer was reached that permitted operation at 0520 hours on April 24th. Two pumps were started manually at 0645 hours, each at 4.0 MGD (175 lps). The chlorinators were turned on at a rate of 333 lbs per MG (40 mg/l). The basins filled and discharge commenced at 1130 hours. By 1300 hours, flow had fallen to 6.7 MGD (293 lps) and at 1330 hours, basin 3 was cut out of service; flow simply wasn't adequate for a test of all three basins and it was hoped that at the very least, sufficient flow would be available to evaluate the performance of the tube settlers by comparing the performance of basins 1 and 2.

Table A-34 shows the evaluation protocol that was intended to be followed. In general, it is a comparative performance evaluation of the three basins at 50% and 100% of design hydraulic loading and low (300-400 mg/l), design (600 mg/l), and high (800-900 mg/l) levels of suspended solids in the flocculator zone achieved by adding waste lime sludges. Before commencing the protocol, however, it was considered desirable to develop additional comparative data using no waste lime addition at all on this day of April 24th.

By 1600 hours, wastewater flow had fallen to 2.2 MGD (96 lps) at which time samples were taken for analysis. The hydraulic loadings, results of the analyses, and the performance of the two basins in terms of BOD_5, COD, and suspended solids removals are shown in Table 7. That the sludge recirculation pumps were on was the project director's error; he had wanted sludge removed, not recirculated. Settleable solids in the influent and effluents are shown for this run but are omitted hereinafter because in all cases and for all runs, regardless of the content in the influent, effluent values were observed as either zero or as a trace. Table 7 shows no major differences in the performance of the two basins at the very low hydraulic loadings utilized.

Table 7. Run No. 5, April 24, 1973

Hydraulic:		Basin 1	Basin 2
Wastewater Flow, MGD/lps		1.0/44	1.2/53
Waste Lime Flow, MGD/lps		0	0
Recirculated Flow, MGD/lps		0.75/33	0.75/33
Overflow Rate,	gpd/ft^2	198	238
	lpm/m^2	5.6	6.7
Tube Settler Rate,	gpm/ft^2	0.65	-
	lpm/ft^2	26.5	

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	57	23	20
COD, mg/l	185	128	145
Sus. Solids, mg/l	108	49	54
Sett. Solids, mg/l	4.0	0.0	0.2
pH, units	7.5	7.2	7.1
Cl_2 Residual, mg/l	-	1.6	3.5
Turbidity, JTU	76	25	27
Total Coliform, MPN/100 ml	-	<2.2	<2.2
Coliphages, pfu/ml	-	134	140

Performance, Percent Removal:		
BOD_5	60	65
COD	31	22
Sus. Solids	55	50

The next morning, sewer flow elevations were still substantially above normal and permission was received to throttle the flow at the outlet of the diversion structure to enable the plant to operate again for Run No. 6. The resulting flow was diverted to basins 1 and 3, and the analytical results of samples taken at the end of the working day as well as the hydraulic loading and performance calculations for this run are shown in Table 8. Once again, no important differences in quality between the two basins can be observed. The better suspended solids removal for basin 1 is accompanied by a lower overflow rate.

On the morning of April 26th, Run No. 7 was also achieved by restricting wastewater flow out of the diversion structure. The 50% and 100% design flows could not be achieved but at least some operational experience was being obtained. Note that the concentration of organics in both influent and effluent were increasing with time:

Date	Influent		Effluent*	
	BOD_5	COD	BOD_5	COD
24	57	180	21.5	136.5
25	78	193	43.5	165
26	120	240	53.5	175

* Averages of two basins

Run 7 shown in Table 9 compares basins 2 and 3, and no differences can be observed. Again, the hydraulic loadings are quite low. (Multiplying the surface loading rate in gpd/ft^2 by a factor of 12.3 gives the weir loading in gpd/ft of weir length.)

Sufficient courage had been generated by now in operating the facility with the main sewer value partially restricting flow to try a full-flow run on one basin. Such a run, no. 8, was tried on April 27. Flow initially was set at 9 MGD total (wastewater + 1 MGD waste lime + 0.75 MGD recirculation). Such a flow submerged the baffles of the flocculators. Hence, flow was reduced to 8 MGD for most of the remainder of the day but had dropped to 7 MGD by the time it was sampled. The results of the samples analyses are shown in Table 10. At the high overflow rate observed, suspended solids removal was quite low even though the flocculator suspended solids were close to the design value.

Table 11 reviews the experience of the three basins in these four runs in terms of overflow rates and effluent qualities of BOD_5, COD, and total suspended solids. Five of the seven BOD_5 values exceeded the State criterion of 40 mg/l for an individual sample. For total suspended solids, only two of the seven values failed to meet the State limit of 50 mg/l for an individual sample. But the alarming factor about these data are that they were obtained at very low overflow rates and the single use of waste lime sludge in treatment re-

Table 8. Run No. 6, April 26, 1973

Hydraulic:	Basin 1	Basin 3
Wastewater Flow, MGD/lps	1.9/83	2.2/96
Waste Lime Flow, MGD/lps	0	-
Recirculated Flow, MGD/lps	0	-
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	370	430
	11	12
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/ft^2}$	1.2	
	60	

Quality:	Influent	Effluent Basin 1	Effluent Basin 3
BOD_5, mg/l	78	45	42
COD, mg/l	193	177	153
Sus. Solids, mg/l	112	32	48
pH, units	7.4	6.9	6.5
Cl_2 Residual, mg/l	-	2.3	4.4
Turbidity, JTU	23	25	24
Total Coliform, MPN/100 ml	-	<2.2	<2.2
Coliphages, pfu/ml	-	430	-

Performance, Percent Removal:		
BOD_5	42	46
COD	8	21
Sus. Solids	71	57

Table 9. Run No. 7, April 26, 1973

Hydraulic:	Basin 2	Basin 3
Wastewater Flow, MGD/lps	1.0/66	2.0/88
Waste Lime Flow, MGD/lps	0	-
Recirculated Flow, MGD/lps	0	-
Overflow Rate, gpd/ft^2	297	396
lpm/m^2	8.4	11.2

	Influent	Effluent	
Quality:		Basin 2	Basin 3
BOD_5, mg/l	120	55	52
COD, mg/l	248	176	176
Sus. Solids, mg/l	110	48	48
pH, units	7.4	6.8	6.9
Cl_2 Residual, mg/l	-	6.5	3.1
Turbidity, JTU	30	25	27
Total Coliform, MPN/100ml	-	>2.2	>2.2
Coliphages, pfu/ml	-	120	140

Performance, Percent Removal:		
BOD_5	54	57
COD	29	29
Sus. Solids	56	56

Table 10. Run No. 8, April 27, 1973

Hydraulic:	Basin 1
Wastewater Flow, MGD/lps	5.25/230
Waste Lime Flow, MGD/lps	1.0/44
Recirculated Flow, MGD/lps	0.75/33
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	1238 / 51
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	4.1 / 166
Flocculator Sus. Solids, mg/l	600

Quality:	Influent	Effluent Basin 1
BOD_5, mg/l	110	49
COD, mg/l	280	160
Sus. Solids, mg/l	146	106
pH, units	7.1	7.2
Cl_2 Residuals, mg/l	-	3.6
Turbidity, JTU	68	57
Total Coliform, MPN/100ml	-	<2.2
Coliphages, pfu/ml	-	500

Performance, Percent Removal:	
BOD_5	55
COD	43
Sus. Solids	27

Table 11. Effluent Quality vs. Overflow Rate

Basin	Overflow Rate gpd/ft²/lpm/m²	BOD5 mg/l	COD mg/l	Suspended Solids mg/l
1	198/5.6	23	128	49
1	376/11	45*	177	32
1	1238/35	49*	160	106*
2	238/6.7	20	146	54*
2	297/8.4	55*	176	46
3	436/12	42*	153	48
3	396/11.2	52*	176	46

* Failed to meet State criteria

resulted in the highest effluent suspended solids value.

Part 2 - Augmented Flows

In order to accelerate the evaluation of the facility, the operation was divorced from the vagaries of the weather through the use of artificially augmented sewer flows. A temporary dam was placed across Joe's Creek which allowed submergence of a sewer manhole. A series of tests utilizing this two-influent system (wastewater plus Joe's Creek water) was conducted in May 1973.

The six runs in May (Runs 9-14) were aimed at comparing the performance of basins 1 and 2 at the two hydraulic loadings (50% and 100% of design or 864 and 1728 gpd/ft^2) (24.5 and 48.9 lpm/m^2) and the three flocculator suspended solids concentrations, 300-400 mg/l, design - 600 mg/l, and 800-900 mg/l, shown in Table A-34.

Run 9, Table 12, was close to the desired 50% hydraulic load and the flocculator suspended solids concentration was at the desired value -- at least in basin 1. But the sample results show no discernible difference in performance of the two basins -- hence, no discernible contribution by the tube settlers in basin 1.

Run 10, Table 13, achieved the higher flocculator suspended solids values desired but the hydraulic load had dropped substantially. Two more efforts were made to achieve high flocculator suspended solids values and a 50% overflow rate, but these Runs, 11 and 12, shown in Tables 14 and 15, fell short of both objectives.

At this time is was found that for Runs 9-11 the flocculator suspended solids were being measured only in the basin 1 flocculator. Hence, the values shown for basin 2 in Tables 12-15 are all estimated values derived from solids balances.

Run No. 13, Table 16, aimed at a low waste lime solids concentration (300-400 mg/l) but actually came out a little high. Poor suspended solids performance is again manifest (throughout all these runs). Run No. 14, Table 17, aimed at a high waste lime solids concentration (800-900 mg/l), and it, too, turned out to be a little high. The relatively high percent suspended solids removal is an artifact of the high influent sample suspended solids; the effluent values are the same as for the preceding runs.

Table 18 compares the BOD_5 and suspended solids values of the influent waters to the plant for the natural flows treated in Runs 1-7 and for the augmented flows treated in Runs 9-14. Run 8 was omitted since that influent was provided by backing up wastewater flow from the diversion structure into the facility. The augmented flows are considerably more concentrated than the natural flows, especially for suspended solids.

The evaluation was resumed with Run No. 15 on July 18th (Table 19). Another comparative performance run between basins 1 and 2 at a high

(800-900 mg/l) waste lime concentration was desired and achieved, but the data was very poor. In order to get additional flow, potable water from a hydrant was added to the sewer--as well as creek water. And in order to get this large flow of water into the plant, it was necessary to keep one man continuously employed cleaning debris from the bar rack in the diversion structure and the bar screen in the wet well. The bar rack in the diversion structure had to be raised several inches to allow cleaning, and this allowed trash to enter the plant.

Run No. 16 on July 19th (Table 20) aimed at a suspended solids concentration in the flocculators of 800-900 mg/l. The results were not only higher, but the two concentrations were quite different. Suspended solids concentrations in the effluents continued to be uniformly high. Analyses on basin 3 were incomplete.

Run NO. 17 (Table 21) aimed at the same treatment and was closer to the target. The results show that the basin without sludge addition produces the better effluent in terms of suspend solids.

Run No. 18 (Table 22) aimed at a lower flocculator suspended solids concentration (300-400 mg/l). It too shows the plain settling basin to produce a better effluent in terms of suspended solids.

Run No. 19 (Table 23) aimed at the design value of flocculator solids (600 mg/l) and the highest possible hydraulic load and by both accounts came close. Again, the basin without sludge addition produced the lowest effluent suspended solids.

Waste lime sludge addition proved fruitless and its operation ceased for remaining evaluations. State criteria require achieving a suspended solids concentration not to exceed 50 mg/l on an individual sample, and the addition of waste lime sludges from the water purification plant was making the standard unattainable -- instead of helping to achieve it.

Part 3 - Polymer Treatments

The final and concluding series of runs were carried out in August 1973. Temporary polymer solution feed equipment was installed and Hercofloc 814.3 was used for testing. Separate pumps fed from the same polymer-containing vat into the Parshall flumes ahead of basins 1 and 2. Control was difficult and equipment inadequate, but the results, shown in Tables 24-26, were at least promising.

Run 20, Table 24, aimed at a 0.5 mg/l polymer feed to basins 1 and 2, as high a hydraulic loading as was possible, and no waste lime sludge addition. The results show that both basins which received polymers discharged effluents that met State standards for suspended solids.

In order to achieve a higher polymer concentration, it was necessary to reduce the facility's flow -- since the polymer pumps were operating

Table 12. Run No. 9, May 14, 1973

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	3.95/171	3.95/171
Waste Lime Flow, MGD/lps	0.5/22	0.5/22
Recirculated Flow, MGD/lps	0.75/33	0.75/33
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	882 35	882 35
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	2.9 118	-
Flocculator Sus. Solids, mg/l	653	620*

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	77	29	29
COD, mg/l	269	139	139
Sus. Solids, mg/l	140	93	100
pH, units	7.4	7.6	7.6
Cl_2 Residual, mg/l	-	0.7	0.2
Turbidity, JTU	145	130	140
Coliphages, pfu/ml	-	231	211

Performance, Percent Removal:		
BOD_5	64	62
COD	48	48
Sus. Solids	34	29

* Estimated

Table 13. Run No. 10, May 15, 1973

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	2.35/103	2.55/112
Waste Lime Flow, MGD/lps	0.5/22	0.5/22
Recirculated Flow, MGD/lps	0.75/33	0.75/33
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	$\frac{565}{16}$	$\frac{604}{17}$
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	$\frac{1.9}{77}$	-
Flocculator Sus. Solids, mg/l	1060	1015*

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	118	20	20
COD, mg/l	399	130	138
Sus. Solids, mg/l	200	120	160
pH, units	7.2	7.2	7.0
Cl2 Residual, mg/l	-	1.3	3.1
Turbidity, JTU	170	120	150
Total Coliform, MPN/100 ml	-	5.1	>16
Coliphage, pfu/ml	-	264	294

Performance, Percent Removal:		
BOD_5	83	83
COD	67	65
Sus. Solids	40	20

* Estimated

Table 14. Run No. 11, May 16, 1973

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	2.99/129	2.75/120
Waste Lime Flow, MGD/lps	0.5/22	0.5/22
Recirculated Flow, MGD/lps	0.75/33	0.75/33
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	684 19	644 18
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	2.25 92	-
Flocculator Sus. Solids, mg/l	744	771*

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	78	46	50
COD, mg/l	390	211	211
Sus. Solids, mg/l	200	120	120
pH, units	7.4	7.3	7.3
Cl_2 Residual, mg/l	-	1.1	0.6
Turbidity, JTU	200	150	160
Total Coliform, MPN/100 ml	-	9.2	≥16
Coliphages, pfu/ml	-	420	500

Performance, Percent Removal:		
BOD_5	42	36
COD	46	46
Sus. Solids	40	40

* Estimated

Table 15. Run No. 12, May 18, 1972

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	2.25/99	3.75/164
Waste Lime Flow, MGD/lps	0.5/22	0.5/22
Recirculated Flow, MGD/lps	0.75/33	0.75/33
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	545 15	842 24
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	1.8 73	-
Flocculator Sus. Solids, mg/l	721	641*

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	101	35	34
COD, mg/l	274	169	161
Sus. Solids, mg/l	160	120	120
pH, units	7.0	7.0	7.2
Cl_2 Residual, mg/l	-	2.3	0.7
Turbidity, JTU	120	140	140
Total Coliform, MPN/100 ml	-	<2.2	>16
Coliphages, pfu/ml	-	240	300

Performance, Percent Removal:		
BOD_5	65	66
COD	38	41
Sus. Solids	25	25

* Estimated

Table 16. Run No. 13, May 23, 1973

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	3.5/153	4.0/175
Waste Lime Flow, MGD/lps	0.3/22	0.3/22
Recirculated Flow, MGD/lps*	0	0
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	753 31	862 34
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	2.5 101	-
Flocculator Sus. Solids, mg/l	440	440

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	131	64	52
COD, mg/l	361	147	147
Sus. solids, mg/l	240	100	120
pH, units	7.4	7.2	7.3
Cl_2 Residual, mg/l	-	0.7	0.7
Turbidity, JTU	130	250	100
Total Coliform, MPN/100 ml	-	16	>16
Coliphages, pfu/ml	-	36	74

Performance, Percent Removal:		
BOD_5	59	60
COD	59	59
Sus. Solids	96	50

* Operated first three-hours of day only at rate of 0.6 MGD(26 lps) each basin.

Table 17. Run No. 14, May 24, 1973

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	3.3/145	3.2/140
Waste Lime Flow, MGD/lps	0.5/22	0.5/22
Recirculated Flow, MGD/lps*	0	0
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	$\frac{753}{31}$	$\frac{733}{31}$
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	$\frac{2.5}{101}$	-
Flocculator Sus. Solids, mg/l	1080	1080

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	129	50	47
COD, mg/l	352	173	173
Sus. Solids, mg/l	520	160	120
pH, units	7.2	7.2	7.2
Cl2 Residual, mg/l	-	2.0	2.0
Total Coliform, MPN/100 ml	-	1100	240
Coliphages, pfu/ml	-	220	200

Performance, Percent Removal:		
BOD_5	61	64
COD	51	51
Sus. Solids	69	77

* Operated first five-hours only at rate of 0.6 MGD (26 lps) each basin.

Table 18. Comparison of Influent Qualities, Natural vs. Augmented Sewer Flows

Run	Natural		Run	Augmented	
	BOD_5	TSS		BOD_5	TSS
1	60	234	9	77	140
2	30	72	10	118	200
3	45	96	11	78	200
4	78	10	12	101	160
5	57	108	13	131	240
6	78	112	14	129	520
7	120	110			
8	110	146			
$\bar{X}$ *	72	111		106	243

at maximum rate. Run 21, Table 25, shows the results at a 1.0 mg/l concentration of polymer. In spite of the lower overflow rates and higher polymer feed rate, effluent quality was not improved.

Jar studies with polymer and waste lime sludge had shown that as little as 0.1 mg/l of polymer reduced the suspended solids from 1500 mg/l down to the range 1 - 10.4 mg/l. Hence, Run 22 aimed at determining whether 1.0 mg/l of polymer would achieve better results if waste lime sludge was also added to the augmented wastewater flow. The results, Table 26, show no improvement, but the operating engineer observed that the solution had deteriorated.

A fresh solution was prepared for Run 23, Table 27. The polymer was prepared in more concentrated form so that a 2.0 mg/l rate of polymer feed could be maintained. The suspended solids results were uniformly the best yet achieved, but the effluent from basin 3 which received no waste lime sludge and no polymer and was serving as a control had the same low suspended solids content.

The last run, No. 24, Table 28, aimed at replicating Run 23 except that a lower polymer concentration was used and it was hoped that a better balance could be achieved in flocculator suspended solids between basins 1 and 2. Both were achieved but the results indicate less effective treatment at this lower polymer application rate. The operating engineer applied 1.0 mg/l for one-half day during this run and then 1.5 mg/l for the remainder of the day.

Operation were concluded because virtually everything possible had been done to achieve flows sufficient for the evaluation of the facility and the methods resorted to were simply too costly to continue.

Table 29 summarizes the effluent suspended solids data determined for each run. The values with an asterisk indicate that waste lime sludge was used in the treatment. Average values for all runs with and without the addition of waste lime sludge compares as follows:

	Suspended Solids, mg/l		
	Basin 1	Basin 2	Basin 3
Sludge used	101	98	-
Sludge not used	13	31	98(44)

The 44 in parenthesis is the average value for basin 3 if the single very high value of 220 measured during Run 20 is omitted from the calculation. The conclusion of these data is that waste lime sludge contributes suspended solids to the effluent.

Tables 30 and 31 present similar summaries for BOD_5 and COD effluent values. Average values of BOD_5 for all runs with and without waste lime sludge addition compares as follows:

Table 19. Run No. 15, July 18, 1973

Hydraulic:	Basin 1	Basin 2
Wastewater Flow, MGD/lps	3.7/162	3.2/140
Waste Lime Flow, MGD/lps	0.3/13	0.2/9
Recirculated Flow, MGD/lps	0.6/26	0.6/26
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	792 32	673 19
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	2.5 106	-
Flocculator Sus. Solids, mg/l	1100	880

Quality:	Influent	Effluent Basin 1	Effluent Basin 2
BOD_5, mg/l	54	46	54
Sus. Solids, mg/l	40	120	120
pH, units	7.2	7.4	7.5
Cl_2 Residual, mg/l	-	5.0	4.2
Turbidity, JTU	130	200	200
Total Coliform, MPN/100 ml	-	<2.2	<2.2

Performance, Percent Removal:		
BOD_5	15	0
Sus. Solids	increase	increase

Table 20. Run No. 16, July 19, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.4/149	3.4/149	4.0/175
Waste Lime Flow, MGD/lps*	0	0	0
Recirculated Flow, MGD/lps	0.6/26	0.6/26	-
Overflow Rate, gpd/ft² lpm/m²	674 19	674 19	793 22
Tube Settler Rate, gpm/ft² lpm/m²	2.2 90	-	-
Flocculator Sus. Solids, mg/l	1480	1080	-

Quality:	Influent	Effluent Basin 1	Effluent Basin 2	Effluent Basin 3
BOD_5, mg/l	60	35	37	-
COD, mg/l	280	132	140	-
Sus. Solids, mg/l	160	160	160	-
pH, units	7.6	7.4	7.3	7.3
Cl₂ Residual, mg/l	-	0.0	0.3	0.0
Turbidity, JTU	140	100	100	95
Total Coliform, MPN/100 ml	-	930	30	-
Coliphages, pfu/ml	-	2100	2300	-

Performance, Percent Removal:			
BOD_5	42	38	-
COD	48	45	-
Sus. Solids	0	0	-

* Turned off at 1445 hrs. Flow rate had been 0.4 MGD (16 lps) in each basin.

Table 21. Run No. 17, July 20, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.6/158	3.6/158	4.0/175
Waste Line Flow, MGD/lps*	0	0	0
Recirculated Flow, MGD/lps	0.4/18	0.4/18	-
Overflow Rate, gpd/ft² lpm/m²	713 29	713 29	793 32
Tube Settler Rate, gpm/ft² lpm/m²	2.3 96	-	-
Flocculator Sus. Solids, mg/l	880	720	-

Quality:	Influent	Effluent Basin 1	Effluent Basin 2	Effluent Basin 3
BOD_5, mg/l	102	53	56	62
COD, mg/l	312	181	189	240
Sus. Solids, mg/l	90	150	150	70
pH, units	7.4	7.2	7.2	7.1
Cl_2 Residual, mg/l	-	1.5	1.0	0.6
Turbidity, JTU	150	200	180	110
Total Coliform, MPN/100 ml	-	<30	>24000	<30
Coliphages, pfu/ml	-	940	2780	900

Performance, Percent Removal:			
BOD_5	48	45	39
COD	42	39	23
Sus. Solids	Increase	Increase	22

* Turned off at 1515 hrs. Flow rates had been 0.16 MGD (7 lps) in Basin 1 and 0.16 MGD (7.0 lps) in Basin 2.

Table 22. Run No. 18, July 23, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.6/158	3.6/158	4.0/175
Waste Lime Flow, MGD/lps*	0	0	-
Recirculated Flow, MGD/lps	0.4/18	0.4/18	-
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	713 29	713 29	793 32
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	2.3 95	-	-
Flocculator Sus. Solids, mg/l	300	260	-

Quality:	Influent	Effluent Basin 1	Effluent Basin 2	Effluent Basin 3
BOD_5, mg/l	76	40	51	60
COD, mg/l	244	141	201	212
Sus. Solids, mg/l	120	140	140	60
pH, units	7.6	7.2	7.0	7.2
Cl_2 Residual, mg/l	-	0.7	0.4**	0.0
Turbidity, JTU	130	170	140	110
Total Coliform, MPN/100 ml	-	>24000	>30	>24000
Coliphages, pfu/ml	-	2200	180	660

Performance, Percent Removal:			
BOD_5	47	33	21
COD	30	16	13
Sus. Solids	Increase	Increase	50

* Turned off at 1230 hrs. Flow rate had been 0.2 MGD (9 lps) in each basin.

** Not an error. It reflects difficulty of chlorination control.

Table 23. Run No. 19, July 24, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	6.6/289	6.2/272	7.2/315
Waste Lime Flow, MGD/lps	0.4/18	0.6/26	-
Recirculated Flow, MGD/lps	0.4/18	0.4/18	-
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	1387 19	1347 18	1427 40
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	4.6	-	-
Flocculator Sus. Solids, mg/l	580	560	-

Quality:	Influent	Effluent Basin 1	Effluent Basin 2	Effluent Basin 3
COD, mg/l	295	196	196	220
Sus. Solids, mg/l	60	80	100	40
pH, units	7.5	7.7	7.3	7.3
Cl2 Residual, mg/l	-	1.0	1.0	2.0
Turbidity, JTU	150	200	200	110
Total Coliform, MPN/100 ml	-	70	>24000	930
Coliphages, pfu/ml	-	1960	320	460

Performance, Percent Removal:	Basin 1	Basin 2	Basin 3
COD	34	34	25
Sus. Solids	Increase	Increase	33

Table 24. Run No. 20, August 2, 1973

Hydraulics:		Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps		6.0/263	5.1/267	5.6/285
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$		1189 34	1209 34	1288 36
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$		3.9 159	"	"
Polymer Feed, mg/l		0.6	0.6	0
	Influent		Effluent	
Quality:		Basin 1	Basin 2	Basin 3
BOD_5, mg/l	96	56	53	61
COD, mg/l	250	105	105	201
Sus. Solids, mg/l	200	40	20	220
pH, units	7.6	7.4	7.4	7.4
Cl_2 Residual, mg/l	-	0.7	0.6	0.9
Turbidity, JTU	136	65	65	95
Total Coliform, MPN/100ml	-	>24000	>24000	>24000
Coliphages, pfu/ml	-	42	10	700
Performance, Percent Removal:				
BOD_5		41	44	36
COD		58	58	20
Sus. Solids		80	90	Increase

Table 25. Run No. 21, August 3, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.8/166	3.8/166	3.8/166
Overflow Rate, gpd/ft^2	753	753	753
lpm/m^2	31	31	31
Tube Settler Rate, gpm/ft^2	2.5	-	-
lpm/m^2	101		
Polymer Feed, mg/l	1.0	1.0	0

	Influent	Effluent		
Quality:		Basin 1	Basin 2	Basin 3
COD, mg/l	304	200	200	224
Sus. Solids, mg/l	100	40	40	40
pH, units	7.4	7.1	7.1	7.2
Cl$_2$ Residual, mg/l	-	0.2	0.1	0.1
Turbidity, JTU	110	80	80	85
Total Coliform, MPN/100 ml	-	>24000	>24000	70
Coliphages, pfu/ml	-	900	600	500
Performance, Percent Removal:				
COD		34	34	26
Sus. Solids		60	60	60

Table 26. Run No. 22, August 6, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.4/149	3.2/140	3.8/166
Waste Lime Flow, MGD/lps*	0	0	-
Recirculated Flow, MGD/lps	0.6/26	0.6/26	-
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	$\frac{674}{19}$	$\frac{634}{18}$	$\frac{753}{21}$
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	$\frac{2.3}{90}$	-	-
Flocculator Sus. Solids, mg/l	860	540	-
Polymer, mg/l**	1.0	1.0	0

Quality	Influent	Effluent Basin 1	Basin 2	Basin 3
BOD_5, mg/l	64	49	50	45
COD, mg/l	293	30*	196	214
Sus. Solids, mg/l	100	60	40	60
pH, units	7.6	7.2	7.2	7.0
Cl_2 Residual, mg/l	<	0.7	0.7	0.5
Turbidity, JTU	140	110	110	110
Total Coliform, MPN/100ml.		2.2	>24000	430

Performance, Percent Removal:			
BOD_5	23	22	30
COD	Increase		27
Sus. Solids	40	60	40

* Turned off at 1320 hrs. Flow rate had been 0.3 MGD (13 lps) in each basin.

** Solution had deteriorated.

Table 27. Run No. 23, August 7, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.0/166	4/175	4/175
Recirculated Flow, MGD/lps	0.2/9	0*	-
Overflow Rate, gpd/ft^2	793	793	793
lpm/m^2	21	22	22
Tube Settler Rate, gpm/ft^2	2.5	-	-
lpm/m^2	101		
Flocculator Sus. Solids, mg/l	720	120*	-
Polymer, mg/l	2.0	2.0	0

Quality:	Influent	Effluent Basin 1	Basin 2	Basin 3
COD, mg/l	360	171	163	203
Sus. Solids, mg/l	100	20	20	20
pH, units	6.0	7.2	7.3	7.0
Cl_2 Residual, mg/l	-	0.9	2.0	2.7
Turbidity, JTU	140	60	70	100
Total Coliform MPN/100 ml	-	>24000	>24000	6.1
Coliphages, pfu/ml	-	960	400	1700

Performance, Percent Removal:			
COD	51	53	42
Sus. Solids	80	80	80

* Basin 2 sludge pump inoperative.

Table 26. Run No. 24, August 8, 1973

Hydraulic:	Basin 1	Basin 2	Basin 3
Wastewater Flow, MGD/lps	3.4/149	3.4/149	4/175
Waste Lime Flow, MGD/lps*	0	0	-
Recirculated Flow, MGD/lps	0.6/26	0.6/26	-
Overflow Rate, $\frac{gpd/ft^2}{lpm/m^2}$	674 19	674 19	793 22
Tube Settler Rate, $\frac{gpm/ft^2}{lpm/m^2}$	2.2 90	-	-
Flocculator Sus. Solids, mg/l	640	680	-
Polymer, mg/l	1.5	1.5	0

Quality	Influent	Effluent Basin 1	Effluent Basin 2	Effluent Basin 3
BOD_5, mg/l	57	20	25	21
Sus. Solids, mg/l	100	60	40	60
pH, units	7.3	7.0	7.0	7.2
Cl_2 Residual, mg/l	-	3.0	4.5	1.5
Turbidity, JTU	100	70	75	90
Total Coliform MPN/100 ml	-	2.2	24000	230

Performance, Percent Removal:			
BOD_5	65	56	63
Sus. Solids	40	60	40

* Turned off at 1515 hrs. Flow rate had been 0.4 MGD (18 lps) in each basin.

	BOD_5, mg/l		
	Basin 1	Basin 2	Basin 3
Sludge used	<35	36	-
Sludge not used	36	36	38

The conclusion can be made from these data that waste lime sludge does not benefit BOD_5 removal -- nor does it add biodegradable materials to the process.

The average values for COD compare as follows:

	COD, mg/l		
	Basin 1	Basin 2	Basin 3
Sludge used	160	154	-
Sludge not used	173	174	191

The array of these average values suggests that the waste lime sludge may have a mild benefit, but in view of the basin 3 performance, even that is questionable.

The data of Table 29 show that augmented flows treated with waste lime sludge discharge higher suspended solids concentrations than naturally occurring flows -- whether treated with waste lime sludge or not. Adding polymers to the augmented flow simply corrects the problem caused by the waste lime sludge addition.

The data of Table 30 show that augmented flows treated with waste lime sludge discharge higher BOD_5 concentrations than naturally occurring flows. Adding polymers to the augmented flows does not help the BOD_5 problem.

The data of Table 31 also show that augmented flows contain higher concentrations of organics and that polymers do not help.

Table 29. Summary of Effluent Suspended Solids Data

Run No.	Suspended Solids, mg/l Basin 1	Basin 2	Basin 3
Naturally Occurring Flows			
1	82*	50*	-
2	22*	24*	23
3	25*	6*	29
4	6	4	20
5	43	64	-
6	32	-	40
7	-	46	46
8	106*	-	-
$\bar{X}$ =	46	31	36
Augmented Flows			
9	93*	100*	-
10	120*	160*	-
11	120*	120*	-
12	120*	120*	-
13	180*	120*	-
14	160*	120*	-
15	120*	120*	-
16	160*	160*	-
17	150*	150*	70
18	140*	140*	60
19	80*	100*	40
$\bar{X}$ =	131	126	57
Polymer-Treated Flows (Basins 1 & 2 only)			
20	40	20	220
21	40	40	40
22	60*	40*	60
23	20*	20	20
24	60*	40*	60*
$\bar{X}$ =	44	32	80

* Waste lime sludges added in treatment

Table 30. Summary of Effluent BOD_5 Data

Run No.	BOD_5, mg/l Basin 1	Basin 2	Basin 3
Naturally Occurring Flows			
1	<15*	<15*	-
2	<12*	<12*	17
3	<12*	<12*	14
4	22	16	6
5	23	20	-
6	45	-	42
7	-	55	52
8	49*	-	-
$\bar{X}$ =	<25	<22	26
Augmented Flows			
9	29*	29*	-
10	20*	20*	-
11	45*	50*	-
12	35*	34*	-
13	64*	52*	-
14	50*	47*	-
15	46*	54*	-
16	36*	37*	-
17	53*	56*	62
18	40*	51*	60
19	-	-	-
$\bar{X}$ =	41	43	61
Polymer-Treated Flow (Basin 1 & 2 only)			
20	56	53	61
21	-	-	-
22	49*	50*	45
23	-	-	-
24	20*	26*	21
$\bar{X}$ =	42	43	42

* Waste flow studyes added in treatment

Table 31. Summary of Effluent COD Data

Run No.	COD, mg/l Basin 1	Basin 2	Basin 3
Naturally Occurring Flows			
1	110*	90*	-
2	80*	80*	120
3	80*	100*	140
4	-	-	-
5	128	145	-
6	177	-	153
7	-	176	176
8	160*	-	-
$\bar{X}$ =	122	118	147
Augmented Flows			
9	139*	139*	-
10	130*	130*	-
11	211*	211*	-
12	169*	161*	-
13	147*	147*	-
14	173*	173*	-
15	-	-	-
16	132*	140*	-
17	181*	189*	240
18	171*	204*	212
19	196*	196*	220
$\bar{X}$ =	166	170	224
Polymer-Treated Flows (Basins 1 & 2 only)			
20	185	185	201
21	200	200	224
22	302*	190*	214
23	171*	163	203
24	-	-	-
$\bar{X}$ =	214	184	210

* Waste lime sludges added in treatment

SECTION IX

SURFACE WATER QUALITY MONITORING

Although the concept of a chemical-physical plant to skim off and treat storm flows can unquestionably be an attractive economic alternative to full treatment, some questions can be posed relative to the merits of its environmental impact. When the plant is operating, it is likely that stream flows will be quite high and hence the relatively small contribution from the plant lost in the resulting dilution. But this might not always be true. Consequently, it was considered desirable to demonstrate any impact -- or lack of impact -- that the facility might have on the Elm Fork receiving waters if it were at all possible. Hence, a surface water quality monitoring program was instituted relative to the evaluation of the Bachman Treatment Facility.

The Elm Fork of the Trinity River rises in the north Texas plain just a few miles (km) south of the Red River which borders Texas and Oklahoma (see Figure 32). Two major impoundments are located on the system, Garza-Little Elm on Elm Fork itself and Grapevine on the Denton Creek tributary which enters Elm Fork about eight miles (12.9 km) downstream of the Garza-Little Elm outlet (Lewisville Dam). Major discharges -- both going into the main-waters of the Fork itself upstream from Lewisville Dam -- are from Gainesville (pop. 13,565 located 25 miles (40.3 km) north of the reservoir) and Denton (pop. 38,864 located 5 miles (8 km) northwest of the Reservoir). Reservoir releases are controlled by the Corps of Engineers according to needs. In periods of drought, virtually all of the releases are consumptively used by municipal water supplies. The three major purification facilities on Elm Fork are the Elm Fork and Bachman Plants of the City of Dallas (192 and 122 MGD capacity (8410 and 6745 lps), respectively), and the Park Cities Filtration Plant (27 MGD -- 1183 lps) which intake is located at the same point as that of the Bachman Plant.

Surface water sampling stations were set up on the Elm Fork of the Trinity River above and below its confluence with Bachman Branch (see Figure 32), and also on Bachman Branch above the treatment facility discharge. Before the monitoring program was implemented, however, Bachman Lake was drained to facilitate the construction of the new Bachman Creek Relief sewer, and the Lake remained drained throughout the period of study.

In the Fall of 1971, it was clear that if the opportunity presented itself (that is, if sufficient precipitation occurred) the contractor was going to operate the treatment facility for shakedown purposes -- which, in fact, did happen -- see Section VIII. Since Elm Fork prior to the operation of the facility was pristine with respect to facility

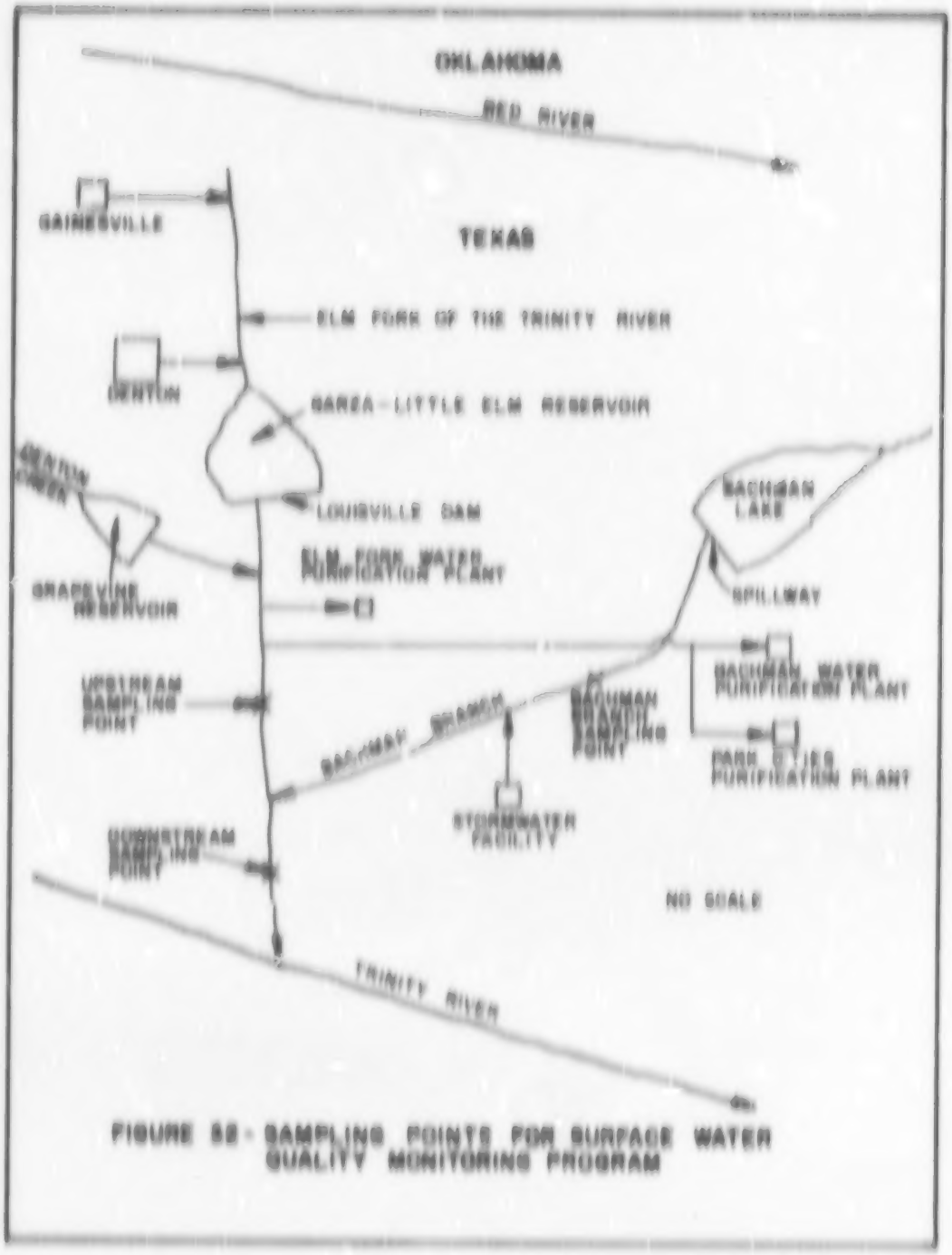


FIGURE 52 - SAMPLING POINTS FOR SURFACE WATER QUALITY MONITORING PROGRAM

discharge, it was desired to obtain background data on at least the coliforms in order to determine any impact on the receiving waters. October being the wettest month, sampling of Elm Fork for coliforms commenced on September 23rd. Purely fortuitously, the facility was operated on Oct. 4 for a short period, and again on October 19th and 20th. The data obtained in this interval are shown in Table 32. Seven sets of samples were taken prior to any discharge, and eight sets of samples were taken after the first discharge occurred. The effect of the facility on the receiving water is most manifest for the fecal coliforms.

From the initiation of the monitoring program through the 13th of June 1972, the Elm Fork sampling stations utilized automatic sampling devices that delivered a measured sample into an iced container each 20 minutes. The amount was not proportional to flow. Sampling was conducted each sixth day. Although the devices worked very well, they were subject to extensive vandalism -- the largest problem being as gun targets. This resulted in increasing unreliability and after June 13th, the samplers and the six-day schedule were abandoned in favor of grab samples taken on Wednesday of every week -- the latter schedule favoring a normal working routine for the field sampling crew. Although the surface sampling protocol originally asked for additional grab samples on days that the treatment facility operated, this too had to be abandoned because of the work load.

The range of values for the parameters tested for each month at the different sampling sites are presented in Tables 33, 34, and 35. The months in which the treatment facility operated are asterisked in Table 35. However, the only month in which extra samples were taken at the same identical time that the facility was discharging was in April 1973.

Since the type of chlorination practiced (a targeted total residual of 1 mg/l) would result only in the combined form (an absence of a free residual), comparatively little effect on viruses could be anticipated[3]. Hence, routine surface water sampling for indigenous phage concomitantly with total and fecal coliforms was initiated in May 1973. The individual analytical findings are presented in Table 36. The log averages of all the microbiological data reveal the following relationships:

	Upstream	Bachman	Downstream
Total MPN/100 ml	5810	14,200	12,650
Fecal MPN/100 ml	900	1,950	2,295
Bacteriophage/ml	1.95	2.13	2.18
Percent of samples Positive for phage	32	58.3	48

Table 32. Coliform MPN's/100 ml on Upstream and Downstream Elm Fork Waters Before and After the Operation of the Treatment Facility.

	UPSTREAM		DOWNSTREAM	
DATE	TOTAL	FECAL	TOTAL	FECAL
BEFORE OPERATION				
9-23-71	11,000	23	110,600	46,000
9-24-71	930	430	24,000	<30
9-27-71	240	90	110,000	750
9-28-71	390	40	4,600	430
9-29-71	2,100	<30	210	430
9-30-71	930	40	750	230
10-1-71	430	<30	430	230
AFTER OPERATION				
10-4-71	110,000	11,000	>240,000	24,000
10-5-71	11,000	930	110,000	46,000
10-6-71	2,400	930	110,000	46,000
10-7-71	11,630	930	24,000	24,000
10-8-71	2,400	930	46,000	24,000
10-19-71	>240,000	110,000	>240,000	240,000
10-26-71	930	43	16,000	210
11-2-71	430	90	280	40

TABLE 36 BACTEROPHAGE PHAGE -- COLIPHAGE RESULTS *

DATE	UPSTREAM			BACKWASH			DOWNSTREAM		
	T	F	Ø	T	F	Ø	T	F	Ø
6/2/74	9,300	900	0	9,300	400	0	29,000	9,900	0
6/9	4,300	900	0	24,000,000	110,000	22	240,000	9,300	10
6/16	9,300	9,300	0	46,000	9,300	9	4,300	9,300	4
6/23	9,300	<300	0	--	--	--	9,300	9,400	4
6/30	24,000	430	0	24,000	210	0	110,000	9,400	0
7/6	15,000	9,300	84	43,000	9,300	9	909	400	4
7/13	9,400	9,300	9	4,300	9,300	0	240,000	93,000	8
7/20	240,000	900	14	46,000	9,300	6	46,000	4,300	18
7/27	46,000	9,200	0	9,300	9,300	9	4,300	930	0
8/3	9,300	400	0	700	300	9	400	400	0
8/11	930	93	0	9,300	90	0	240,000	9,300	0
8/18	4,600	430	14	43,000	9,100	6	400	400	24
8/25	9,400	9,400	0	9,100	430	9	46,000	930	9
9/1	21,000	4,300	4	7,500	9,100	9	4,300	910	9
9/15	9,900	150	0	46,000	9,100	9	4,300	760	0
9/22	4,600	90	0	40	40	0	930	930	0
9/29	430	430	0	>240,000	110,000	6	9,400	9,400	0
9/5	9,400	930	0	240,000	240,000	4	9,300	9,300	0
9/12	>240,000	46,000	4	110,000	24,000	0	240,000	110,000	9
9/19	7,500	930	6	>240,000	9,300	0	240,000	930	9
9/26	9,200	900	0	150,000	20,000	0	43,000	15,000	0
10/3	7,500	400	0	9,300	900	9	9,300	900	0
10/10	9,400	43	0	930	150	0	4,300	430	0
10/17	110,000	15,000	4	15,000	930	4	100,000	9,100	0
10/24	24,000	4,300	0	9,100	930	0	46,000	11,000	0

*T in MPN/100 ml
F in MPN/100 ml
Ø in PFU/ml

In obtaining the log averages for the coliforms, the five indeterminate results of Table 36 were omitted from the calculations. The effects on the above tabulation, had the results been finite, would have been to raise each of the total coliform average values higher and to lower the fecal coliform average value on the upstream sampling site insignificantly lower -- thus changing none of the relativity shown by the above log average coliform calculations. The inference from the above tabulation is that a source of pollution between the upstream and downstream sampling sites on Elm Fork caused deterioration in fecal coliform and bacteriophage quality since both are higher than can be attributed to the Bachman Branch contribution. The amount, however, is very small.

If the data from Table 33 are tabulated for month of occurrence of maxima (and minima where appropriate), the following pattern emerges:

Non-operating Months:

December 1972
Highest total P (0.9 mg/l), highest Org. N (20.6 mg/l), highest NH_3 (2.1 mg/l), highest COD (2040 mg/l), highest suspended solids (36,824 mg/l), and highest total coliforms (shared with September 1973, >240,000/100 ml).

October 1972
Highest NO_2 + NO_3 (4.9 mg/l).

September 1973
Highest total coliforms (shared with December 1972, >240,000/100 ml), and highest fecal coliforms (110,000/100 ml).

February 1972
Highest pH (8.5).

August 1972
Lowest pH (6.6).

September 1972
Highest BOD_5 (22 mg/l).

Operating Months:

November 1972
Lowest D.O. (0.0 mg/l)

July 1973
Highest bacteriophage (24/ml).

Thus, from this review the only parameters that appear to reflect an impact of the treatment facility on the receiving waters are dissolved oxygen, bacterial viruses, and fecal coliforms, the latter two in very small magnitude, and the former on only one occasion.

SECTION X

IMPACT OF SOLIDS ON DALLAS PLANT

Solids separated from the flows at the Bachman Treatment Facility are discharged to the East-Bank Interceptor and then flow to the Dallas Wastewater Treatment Plant, ultimately depositing in two anaerobic digesters. The digesters are routinely monitored by Wastewater Treatment Division personnel for influent total solids (TS), gallons fed, and gas production, and for temperature on a daily basis. Samples for pH and volatile solids (VS) content of both influent and effluent are assayed weekly. These data were averaged by the month for each of the digesters from August 1971 through November 1973 and are presented in Tables 37 and 38 (metric units in Tables 37a and 38a, respectively). The digesters are identified as Nos. 3 and 4 -- Nos. 1 and 2 at the same site are associated with another plant.

Both TS and VS are recorded as percent. In calculating the gas production per unit weight of VS added, a specific gravity of unity was used. Since sludge has a specific gravity greater than one, the simplified calculation results in a larger gas production per unit weight of VS added than would actually be the case. However, the absolute value is unimportant in this review of the data since a relativity is being sought, viz., what are the differences in this parameter when waste lime sludge was added as compared to periods when it was not added?

In Tables 37 and 38 (also 37a and 38a) the months in which the treatment facility operated are indicated by asterisks. A single asterisk indicates that waste lime sludges were used in the treatment and a double asterisk indicates the facility was operated but waste lime sludges were not utilized. There are no indications by these data that the waste lime sludges had any effect whatsoever on the performance of these two digesters.

Table 39 (39a for metric units) shows the daily performance of Digester No. 3 during the month of July 1973. This was the month during which polymers were being used, and the data are presented to show that polymers also had no discernible effect on digester operation.

In October 1973, the manager of the Wastewater Treatment Division related breakdown of screening and grit removal facilities at the Dallas Wastewater Treatment Plant to chunks of solids that bore a resemblance to ferric hydroxide-activated carbon agglomerates. It was postulated that waste lime sludges had settled in various parts of the sewerage system, matted, and then broke loose in chunks. No analyses were performed on these agglomerates; in fact, the Project

Table 37. No. 3 Digester Monthly Data

1971										
Aug.	5.3	4.8	80.7	100.5	248	99	7.0	3.6	62.7	7.64
Sept.	5.7	4.9	78.7	101.8	247	98	7.0	3.6	61.8	7.54
Oct.*	5.7	5.3	71.[illegible]	82.3	210	99	6.9	3.8	64.2	8.05
Nov.	6.0	4.9	82.[illegible]	87.4	213	99	7.0	3.6	60.5	7.27
Dec.	5.6	5.4	76.8	44.4	116	99	7.0	4.0	58.9	7.58
1972										
Jan.	5.5	5.3	79.4	72.6	258	98	6.9	3.9	59.4	10.12
Feb.	5.3	4.9	79.8	81.7	286	99	6.9	3.5	63.5	10.73
Mar.	5.5	5.0	81.2	85.0	276	100	7.2	3.2	65.9	9.59
Apr.	5.5	4.6	81.9	70.5	201	100	7.1	3.5	66.6	9.07
May	5.6	4.5	80.1	75.2	223	100	7.0	3.3	65.0	9.86
June	5.5	4.4	82.8	68.5	146	100	6.9	3.3	63.9	7.01
July	5.7	3.9	80.3	86.4	175	100	7.0	2.8	64.7	7.75
Aug.	5.8	4.1	79.4	84.1	240	100	7.0	2.8	66.2	10.51
Sept.	5.7	4.6	79.9	90.2	283	100	6.9	3.4	68.6	10.30
Oct.*	6.0	5.1	78.1	90.1	235	101	7.0	2.6	62.0	7.85
Nov.**	5.9	5.1	82.0	88.6	251	99	6.9	2.9	64.4	8.16
Dec.*	5.8	4.8	83.9	86.0	222	98	6.9	2.7	66.0	7.69
1973										
Jan.*	5.7	4.8	81.1	79.0	192	97	7.1	3.2	67.2	7.49
Feb.	6.0	4.9	81.6	59.3	154	99	7.3	3.3	58.8	7.79
Mar.	6.1	4.5	77.1	75.6	208	99	7.3	2.3	60.6	9.51
Apr.**	6.0	4.9	78.0	78.0	254	99	7.2	2.6	60.2	10.22
May *	6.1	5.0	75.7	64.2	193	99	7.1	3.5	57.5	8.71
June	6.0	5.4	75.8	63.1	177	99	7.0	3.0	55.6	8.19
July *	5.7	4.5	70.6	80.4	233	100	7.0	2.0	60.9	13.90
Aug. *	6.0	4.3	77.9	89.3	283	100	7.0	2.0	63.9	11.30
Sept.	5.9	4.9	75.4	74.8	240	100	6.9	2.1	67.1	10.40
Oct.	6.0	4.6	76.5	65.0	205	100	7.1	2.0	69.8	10.60
Nov.	6.2	5.2	79.4	97.7	289	99	7.0	2.0	66.6	8.61

* Facility operated with waste time sludge addition

** Facility operated but no waste time sludge addition

Table 37a. No. 3 Digester Monthly Data, Metric Units

	Feed M^3/day	Gas Production M^3/day	Temp °C	M^3 Gas Produced per Kg VS added
1971				
Aug.	380.4	7018.4	37.2	0.476
Sept.	386.3	6990.1	36.7	0.470
Oct.*	311.5	5943.0	37.2	0.502
Nov.	330.8	6027.9	37.2	0.453
Dec.	168.1	3283	37.2	0.473
1972				
Jan.	274.8	7301	36.7	0.631
Feb.	309.2	8094	37.2	0.669
Mar.	321.7	7811	37.8	0.598
Apr.	266.8	5608	37.8	0.566
May	284.6	6311	37.8	0.615
June	259.3	4132	37.8	0.437
July	327.0	4952	37.8	0.484
Aug.	318.3	6791	37.8	0.655
Sept.	341.4	8009	37.8	0.638
Oct.*	341.0	6650	38.3	0.490
Nov.**	335.4	7103	37.2	0.506
Dec.*	326.6	6283	36.7	0.479
1973				
Jan.*	299.0	5434	36.1	0.467
Feb.	224.4	4358	37.2	0.486
Mar.	286.1	6886	37.2	0.593
Apr.**	295.8	7188	37.2	0.637
May *	243.0	5462	37.2	0.594
June	236.8	5009	37.2	0.512
July *	304.3	6594	37.8	0.602
Aug.*	338.0	8009	37.8	0.707
Sept.	283.1	6792	37.8	0.649
Oct.	249.1	5802	37.8	0.662
Nov.	369.8	8179	37.2	0.536

* Facility operated with waste time sludge addition

** Facility operated but no waste time sludge addition

Table 38. No. 4 Digester Monthly Data

1971										
Aug.	5.3	4.6	80.7	99.2	234	100	7.0	3.3	61.9	7.62
Sept.	5.7	4.8	78.7	98.2	233	100	7.0	3.4	61.1	7.53
Oct.*	5.7	5.2	71.7	79.3	196	102	6.9	3.6	63.7	8.05
Nov.	5.0	4.8	82.0	84.7	204	99	7.0	3.6	63.6	7.34
Dec.	5.6	5.4	76.5	43.2	104	98	7.0	4.0	59.0	6.99
1972										
Jan.	5.5	5.2	79.4	72.5	249	94	6.9	3.8	58.6	9.97
Feb.	5.3	5.0	79.8	82.1	280	95	6.8	3.2	62.4	10.25
Mar.	5.5	4.9	81.2	85.4	262	99	7.2	2.6	65.9	9.26
Apr.	5.5	4.8	81.9	82.4	165	99	7.2	1.2	64.7	6.11
May	5.6	4.5	80.1	75.0	197	100	7.0	3.0	63.8	8.74
June	5.5	4.4	82.8	80.7	120	100	6.9	3.2	62.7	4.89
July	5.7	3.8	80.3	78.0	141	100	7.0	2.6	64.3	7.10
Aug.	5.8	3.8	79.4	82.2	223	100	7.0	2.6	64.7	10.78
Sept.	5.7	4.4	79.9	91.0	259	100	6.9	3.2	65.8	10.08
Oct.*	6.0	4.8	78.1	89.0	215	100	6.9	2.4	62.2	7.73
Nov.**	5.9	4.9	82.0	88.3	217	97	7.0	2.8	60.8	7.43
Dec.*	5.8	4.9	83.9	85.9	197	94	6.8	2.8	66.2	6.69
1973										
Jan.*	5.7	4.8	81.1	69.7	158	94	6.9	3.2	62.0	6.98
Feb.	6.0	5.0	81.6	80.9	124	95	7.1	3.3	62.0	5.98
Mar.	6.1	4.6	77.1	76.7	178	99	7.2	2.3	60.2	7.63
Apr.**	6.0	5.0	78.0	77.0	223	99	7.2	2.6	64.0	8.90
May *	6.1	5.1	78.7	60.8	159	99	7.1	3.5	58.1	8.12
June	6.0	5.4	75.8	61.2	142	99	7.0	3.0	52.3	6.80
July*	5.7	4.4	70.6	79.6	204	99	7.0	2.0	58.7	9.89
Aug.*	6.0	4.2	77.9	89.2	262	99	6.9	2.0	61.6	10.76
Sept.	5.9	5.0	75.4	68.9	213	99	6.9	2.1	60.3	7.61
Oct.	6.0	4.6	76.5	65.7	177	99	7.1	2.0	63.6	9.18
Nov.	6.2	5.2	79.4	96.3	260	99	7.0	2.0	65.6	7.84

* Facility operated with waste time sludge addition

** Facility operated but no waste time sludge addition

Table 46a. No. 4 Digester Monthly Data, Metric Units

	Feed	Gas Production	Temp	M^3 Gas Produced per Kg VS added
	M^3/day	M^3/day	°C	
1971				
Aug.	375.4	6622	37.8	0.476
Sept.	371.7	6594	37.8	0.470
Oct.*	300.2	5547	38.9	0.496
Nov.	320.6	5773	37.1	0.467
Dec.	163.5	2943	36.7	0.436
1972				
Jan.	274.4	7047	34.4	0.622
Feb.	310.7	7924	36.0	0.639
Mar.	323.2	7415	37.2	0.577
Apr.	311.9	4670	37.2	0.381
May	283.9	5575	37.8	0.545
June	306.4	3396	37.8	0.305
July	295.2	3990	37.8	0.443
Aug.	311.1	6311	37.8	0.672
Sept.	344.4	7613	37.8	0.629
Oct.*	336.9	6084	37.8	0.482
Nov.**	334.2	6141	36.1	0.467
Dec.*	325.1	6575	34.4	0.417
1973				
Jan.*	263.0	4471	34.4	0.435
Feb.	230.5	3509	35.0	0.373
Mar.	290.3	5037	37.2	0.489
Apr.**	291.4	6311	37.2	0.555
May *	230.1	4500	37.2	0.507
June	231.6	4019	37.2	0.424
July *	301.3	5773	37.2	0.617
Aug.*	337.6	7415	37.2	0.671
Sept.	336.5	6028	37.2	0.475
Oct.	248.7	5009	37.2	0.572
Nov.	364.5	7358	37.2	0.489

* Facility operated with waste time sludge addition

** Facility operated but no waste time sludge addition

Table 39. No. 3 Digester Daily Data for July 1971

Day	pH	Alk.	Alk.	Gas Prod.	Gas Prod.	Gas Conc.	pH	Alk.	Alk.	Gas Prod.
1		4.9		82.8	256	100		2.0		
2		4.7		88.5	221	99		2.0		
3	6.9	5.6	70.5	94.8	267	100	6.9	2.0	61.3	8.54
4		4.5		98.0	216	100		2.0		
5		4.7		94.2	240	99		2.0		
6		4.7		92.8	248	100		2.0		
7		5.2		97.2	271	99		2.0		
8		5.3		57.0	236	99		2.0		
9		5.3		56.7	166	100		2.0		
10	5.6	4.0	69.6	57.9	177	100	7.0	2.0	58.5	15 82
11		4.0		71.1	204	99		2.0		
12		4.0		70.2	260	99		2.0		
13		4.7		67.5	270	100		2.0		
14		4.6		82.5	259	100		2.0		
15		4.9		83.2	241	100		2.0		
16		5.0		83.4	203	100		2.0		
17	5.7	4.7	73.5	77.0	209	99	7.0	2.0	60.6	9.42
18*		4.2		85.2	244	99		2.0		
19*		4.0		84.9	256	100		2.0		
20*		3.9		78.0	242	100		2.0		
21		4.5		79.0	243	100		2.0		
22		4.4		79.8	242	100		2.0		
23*		4.3		78.3	236	100		2.0		
24*	6.6	4.7	75.0	82.8	245	100	7.0	2.0	62.1	10.05
25		3.8		88.0	226	100		2.0		
26		3.9		91.6	220	100		2.0		
27		3.0		77.7	197	99		2.0		
28		4.0		75.0	228	100		2.0		
29		4.3		80.7	223	99		2.0		
30		5.2		80.0	195	99		2.0		
31	6.8	4.0	64.6	78.0	234	100	7.0	2.0	62.0	11.53

* Treatment facility operated

Table 39a. No. 3 Digester Daily Data for July 1973, Metric Units

	Feed M^3/day	Gas Production M^3/day	Temp °C	M^3 Gas Produced per Kg VS added
1	319.4	7246	37.8	
2	335.0	6264	37.2	
3	358.8	7566	37.8	0.533
4	370.9	7301	37.8	
5	356.5	6792	37.2	
6	351.2	7018	37.8	
7	367.9	7869	37.2	
8	415.7	6650	36.7	
9	214.6	4698	37.8	
10	219.2	5009	37.8	0.621
11	269.1	5773	37.2	
12	266.7	7358	37.2	
13	255.5	7641	37.8	
14	312.3	7330	37.8	
15	314.9	6820	37.8	
16	315.7	6745	37.8	
17	291.4	5915	37.2	0.588
18 *	322.5	6905	37.2	
19 *	321.3	7245	37.8	
20 *	295.2	6049	37.8	
21	299.0	6877	37.8	
22	302.0	6849	37.8	
23 *	296.4	6679	37.8	
24 *	313.4	6934	37.8	0.658
25	333.1	6396	37.8	
26	346.7	6226	37.8	
27	254.1	5575	37.2	
28	283.9	6452	37.8	
29	305.4	6481	37.2	
30	302.8	5510	37.2	
31	296.2	6622	37.8	0.568

* Treatment facility operated

Director did not even see them. No subsequent problems of that type recurred, not even with respect to the digesters.

SECTION XI

REFERENCES

1. Albert Halff Assoc., Inc. Flood Loss Prevention, Bachman Branch Basin. Report for the City of Dallas (June 15, 1969).

2. Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Assn., 1740 Broadway, New York, N.Y., 10019.

3. Kruse, C.W., et al. Halogen action on bacteria, viruses, and protozoa. Proceedings of the National Specialty Conference on Disinfection. American Society of Civil Engineers, 1970, pp. 113-136.

Appendix

Table A-1. Flow in 60 in. (152.4 cm) diameter interceptor calculated from Manning's equation using n = 0.313.

Depth Inches (cm)	Flow MGD (l/s)	Depth Inches (cm)	Flow MGD (l/s)
12 (30.5)	2.7 (118.3)	36 (91.4)	20.3 (889.1)
13 (33.0)	2.9 (127.0)	37 (94.0)	21.2 (928.6)
14 (35.6)	3.5 (153.3)	38 (96.5)	22.1 (968.0)
15 (38.1)	3.8 (166.4)	39 (99.1)	23.0 (1007.4)
16 (40.6)	4.4 (192.7)	40 (101.6)	24.1 (1055.6)
17 (43.2)	5.1 (223.4)	41 (104.1)	25.0 (1095.0)
18 (45.7)	5.7 (249.7)	42 (106.7)	25.9 (1134.4)
19 (48.3)	6.2 (271.6)	43 (109.2)	26.8 (1173.8)
20 (50.8)	6.9 (302.2)	44 (111.8)	27.7 (1213.3)
21 (53.3)	7.5 (328.5)	45 (114.3)	28.6 (1252.7)
22 (55.9)	8.0 (350.4)	46 (116.8)	29.6 (1296.5)
23 (58.4)	8.8 (385.4)	47 (119.4)	30.5 (1335.9)
24 (61.0)	9.7 (424.9)	48 (121.9)	31.2 (1366.6)
25 (63.5)	10.4 (455.5)	49 (124.5)	31.9 (1397.2)
26 (66.0)	11.1 (486.2)	50 (127.0)	32.8 (1436.6)
27 (68.6)	11.9 (521.2)	51 (129.5)	33.8 (1480.4)
28 (71.1)	12.8 (560.6)	52 (132.1)	34.5 (1511.1)
29 (73.7)	13.7 (600.1)	53 (134.6)	35.6 (1559.3)
30 (76.2)	14.6 (639.5)	54 (137.2)	36.0 (1576.8)
31 (78.7)	15.3 (670.1)	55 (139.7)	36.5 (1598.7)
32 (81.3)	16.2 (709.6)	56 (142.2)	37.0 (1620.6)
33 (83.8)	17.2 (753.4)	57 (144.8)	37.4 (1638.1)
34 (86.4)	18.1 (792.8)	58 (147.3)	37.6 (1646.9)
35 (88.9)	19.2 (841.0)	59 (149.9)	37.4 (1638.1)
		60 (152.4)	36.5 (1598.7)

Table A-2. Average sewer flows for sampling hours of April 1971

Date	Hour of Day - MGD (lps) 0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X	s
5	9.4 (412)	5.5 (241)	4.5 (197)	10.9 (477)	7.8 (342)	7.7 (337)	6.9 (302)	7.6 (333)	
7	-	-	4.6 (201)	9.8 (429)	7.7 (337)	7.9 (346)	7.2 (316)	-	
9	7.3 (320)	3.0 (131)	4.6 (201)	9.8 (429)	7.5 (329)	7.6 (333)	6.9 (302)	6.6 (289)	
11	6.9 (302)	3.3 (145)	3.4 (149)	9.1 (399)	7.4 (324)	7.3 (320)	7.7 (337)	6.5 (272)	
13	8.3 (364)	2.9 (127)	4.7 (206)	9.9 (434)	7.7 (337)	7.7 (337)	7.5 (329)	6.9 (302)	
15	7.7 (337)	3.2 (140)	5.2 (228)	9.3 (407)	7.4 (324)	7.7 (337)	7.0 (307)	6.8 (298)	
17	7.5 (329)	4.1 (180)	4.4 (193)	10.9 (477)	9.3 (407)	13.1 (574)	15.3 (670)	8.5 (369)	
19	12.9 (565)	7.6 (333)	10.6 (464)	15.3 (670)	12.0 (526)	11.9 (521)	11.7 (512)	11.7 (512)	
21	11.7 (512)	6.0 (263)	9.0 (394)	13.5 (591)	10.6 (464)	11.0 (482)	10.6 (464)	10.3 (451)	
23	9.3 (407)	4.0 (175)	6.2 (272)	10.7 (469)	8.5 (369)	8.5 (372)	7.0 (307)	7.8 (342)	
25	7.0 (307)	3.8 (166)	3.8 (166)	10.2 (447)	8.6 (377)	7.9 (346)	9.3 (407)	6.9 (302)	
27	8.7 (381)	3.4 (149)	4.4 (193)	9.4 (412)	7.4 (324)	7.6 (333)	8.3 (364)	6.9 (302)	
29	7.4 (324)	3.0 (131)	4.3 (188)	9.1 (399)	7.3 (320)	7.7 (337)	7.6 (333)	6.6 (289)	

cont'd

Table A-2 continued

Date	Hour of Day - MGD (lps)							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
X wet	10.8 (447)	5.4 (237)	6.9 (302)	12.3 (539)	9.6 (420)	13.4 (466)	10.3 (461)	9.1 (399)
X dry	7.6 (333)	3.2 (140)	4.4 (193)	9.6 (420)	7.6 (333)	7.7 (337)	7.7 (337)	6.7 (293)

* X = Daily average (calculation excludes last column)

Table A-3. COD analytical results for sampling hours of April 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
5	356	178	257	469	388	367	592	335
7	577	265	306	566	364	727	646	460
9	545	283	263	1071	460	420	500	507
11	1100	200	140	520	1060	800	421	637
13	318	215	199	447	345	853	1102	396
15	460	260	161	481	360	620	520	394
17	241	220	101	503	-	-	844	266
19	284	201	284	621	541	341	681	379
21	303	121	244	365	305	305	244	274
23	645	121	667	444	363	345	404	414
25	606	141	101	505	687	505	404	424
27	482	121	261	567	483	524	564	406
29	600	340	405	647	500	520	500	501
X wet	346	168	311	480	399	340	553	334
X dry	586	231	229	600	532	621	582	467

* X - Daily average (calculation excludes last column)

Table A-4. BOD_5 analytical results for sampling hours of April 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0650-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
5	170	88	83	210	190	170	210	152
7	210	95	130	190	150	250	230	171
9	220	67	59	260	250	230	310	181
11	310	120	83	270	290	280	270	226
13	300	98	120	330	170	240	190	210
15	260	78	100	180	160	260	260	173
17	190	75	68	250	200	-	-	149
19	110	45	68	320	260	210	200	169
21	220	53	120	180	150	180	170	150
23	250	35	88	220	180	170	200	157
25	200	70	83	160	280	240	230	172
27	240	60	76	190	120	140	210	138
29	240	-	130	95	170	180	170	163
$\bar{X}$ wet	180	59	85	236	196	183	195	155
$\bar{X}$ dry	248	84	98	209	199	228	234	179

* $\bar{X}$ - Daily average (calculation excludes last column)

Table A-5. Total suspended solids analytical results for sampling hours of April 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
5	134	68	164	252	166	126	152	152
7	154	74	160	190	162	356	298	183
9	292	106	82	376	184	210	312	193
11	304	120	74	252	352	238	256	223
13	130	110	92	247	146	250	516	161
15	152	226	108	178	140	342	234	191
17	106	136	88	84	-	-	130	104
19	130	214	90	200	356	180	188	196
21	122	140	132	154	174	156	100	146
23	162	216	172	146	132	118	138	156
25	162	52	12	202	86	224	208	123
27	240	62	100	248	148	318	336	166
29	262	62	152	370	278	424	282	258
X wet	131	155	129	167	207	145	142	151
X dry	201	102	96	258	187	296	305	190

* X - Daily average (calculation excludes last column)

Table A-6. Methylene-blue active substances (MBAS) for sampling hours of April 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
5	2.7	1.8	1.8	5.8	3.7	3.6	3.7	3.2
7	1.8	0.9	0.9	3.8	6.6	4.2	2.8	3.1
9	5.2	2.8	2.1	4.1	3.2	1.7	2.0	3.2
11	2.0	1.6	1.2	1.6	2.4	3.7	4.4	2.1
13	4.1	1.3	1.2	4.1	3.0	3.6	3.3	2.9
15	4.1	1.2	1.7	3.3	4.1	3.2	3.6	2.9
17	1.5	0.6	0.6	2.5	3.2	-	2.8	1.7
19	2.1	1.4	2.3	1.6	4.7	5.5	2.5	2.9
21	1.6	0.0	2.6	5.9	5.7	5.4	1.0	3.5
23	1.7	0.9	0.7	3.6	3.7	3.5	2.9	2.4
25	2.0	1.4	0.5	1.9	4.1	4.3	3.9	2.4
27	4.7	2.0	0.9	6.3	7.4	6.2	5.8	4.6
29	3.9	2.2	3.5	2.8	3.0	4.6	4.1	3.3
X wet	1.9	1.0	1.6	3.9	4.2	4.5	2.6	2.7
X dry	3.5	1.7	1.5	3.5	4.2	4.0	3.7	3.1

* X - Daily average (calculation excludes last column)

Table A-7. Conductivity analytical results for sampling hours of April 1971

Date	Hour of Day - μmhos							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
6	654	677	738	785	781	726	716	727
7	663	663	630	767	690	690	690	650
9	697	695	746	810	658	634	612	706
11	573	589	666	737	603	603	569	628
13	654	650	615	758	651	671	716	650
15	707	697	757	815	815	662	768	742
17	-	698	698	-	662	662	671	678
19	785	828	839	848	813	767	657	813
21	707	757	785	757	809	757	716	762
23	662	707	828	815	671	671	614	726
25	663	757	757	844	703	684	654	735
27	697	645	697	837	746	671	606	716
29	684	697	731	757	746	707	688	720
$\bar{X}$ wet	702	733	778	801	748	717	675	741
$\bar{X}$ dry	667	661	700	791	689	653	650	693

* $\bar{X}$ - Daily average (calculation excludes last column except for 17th)

Table A-8. Total alkalinity analytical results for sampling hours of April 1971

Date	Hour of Day - mg/l as $CaCO_3$							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
5	181	193	207	203	185	187	176	193
7	173	181	196	195	181	183	167	185
9	171	190	191	204	171	176	178	182
11	167	186	190	198	178	182	172	184
13	166	175	196	199	192	179	161	184
15	170	175	197	195	189	195	171	187
17	-	205	214	-	182	175	182	192
19	222	220	231	198	203	197	191	212
21	198	224	221	199	202	205	195	208
23	180	206	227	195	195	206	193	201
25	185	210	212	131	190	187	170	186
27	167	195	205	184	172	189	172	185
29	171	175	205	184	198	192	171	188
X wet	195	210	219	199	193	194	187	201
X dry	171	185	199	186	184	185	170	185

* X = Daily average (calculation excludes last column except for 17th)

Table A-9. Chloride analytical results for sampling days of April 1971

Date	Hour of Day - mg/l as NaCl							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
5	55	55	55	56	57	61	61	57
7	65	51	55	75	67	76	81	69
9	61	62	63	76	70	62	57	66
11	51	50	55	52	58	56	54	54
13	59	50	50	57	62	83	73	60
15	52	50	53	67	71	59	52	59
17	-	55	47	-	53	47	42	49
19	48	48	51	56	58	59	50	53
21	56	53	55	71	68	59	53	60
23	51	52	53	58	59	55	53	55
25	53	53	56	58	57	57	55	56
27	62	49	55	79	68	64	55	66
29	54	53	54	54	67	62	78	57
X wet	53	53	52	60	59	56	52	55
X dry	57	52	55	65	68	65	63	60

* X - Daily average (calculation excludes last column except for 17th)

Table A-10. Average sewer flows for sampling hours of June 1971

Date	Hour of Day - MGD (lps)							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
1	8.3 (364)	3.4 (149)	5.0 (220)	10.4 (456)	8.1 (355)	7.7 (337)	7.5 (329)	7.2 (315)
3	6.8 (298)	2.8 (123)	3.9 (171)	8.8 (385)	7.2 (315)	6.8 (298)	6.8 (298)	6.0 (263)
6	6.1 (267)	2.8 (123)	3.0 (131)	8.8 (385)	7.1 (311)	7.0 (307)	5.9 (258)	5.8 (254)
7	6.3 (276)	2.9 (127)	3.7 (162)	9.6 (420)	7.5 (329)	7.1 (311)	6.4 (280)	6.2 (272)
9	6.7 (293)	2.7 (118)	3.4 (149)	8.2 (359)	6.8 (298)	7.3 (307)	6.5 (285)	5.8 (254)
11	6.7 (293)	2.8 (123)	3.5 (153)	8.6 (377)	7.2 (315)	6.9 (302)	5.9 (258)	6.0 (263)
13	5.7 (250)	2.9 (127)	2.8 (123)	7.7 (337)	7.2 (315)	6.5 (285)	-	5.5 (241)
16	6.7 (292)	2.7 (118)	3.5 (153)	7.9 (346)	7.0 (307)	7.3 (320)	6.7 (293)	5.8 (254)
17	6.7 (293)	2.8 (123)	3.5 (153)	8.2 (359)	6.7 (293)	6.7 (293)	6.4 (280)	5.8 (254)
19	5.3 (232)	2.7 (118)	2.6 (114)	7.8 (342)	6.3 (276)	6.3 (276)	4.9 (215)	5.2 (228)
21	5.3 (232)	2.4 (105)	3.1 (136)	11.4 (499)	8.0 (350)	7.4 (324)	6.7 (293)	6.3 (276)
23	6.6 (289)	-	5.2 (228)	8.0 (350)	6.3 (276)	5.9 (258)	5.9 (258)	-
26	5.8 (254)	2.6 (110)	3.7 (162)	7.9 (346)	6.7 (293)	6.2 (272)	5.3 (232)	5.5 (241)

cont'd

Table A-10 continued

Date	Hour of Day - MGD (lps)							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
27	6.2 (226)	3.6 (114)	2.4 (105)	7.2 (315)	6.4 (280)	5.8 (254)	5.9 (258)	4.9 (215)
29	6.9 (302)	2.7 (118)	3.7 (162)	8.5 (372)	7.4 (324)	7.6 (333)	7.4 (324)	6.1 (267)

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-11. Total COD analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
1	426	183	183	583	396	455	475	386
3	485	263	404	566	606	667	505	499
5	606	343	242	828	545	566	788	588
7	889	323	304	690	714	734	490	603
9	566	263	768	727	507	446	650	502
11	465	263	182	586	420	680	800	485
13	420	260	220	820	700	660	420	500
15	620	260	460	1035	537	438	577	461
17	525	141	404	646	525	687	1111	577
19	788	303	202	747	525	505	525	442
21	485	283	303	788	485	485	586	485
23	563	422	382	643	480	520	660	524
25	574	257	337	653	515	614	554	501
27	574	337	317	594	614	396	554	484
29	525	263	283	1555	545	505	525	600

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-12. "Dissolved" COD analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
1	163	73	89	203	168	144	144	141
3	193	105	177	218	129	177	193	170
5	251	267	194	243	243	178	122	196
7	154	122	170	162	204	179	179	167
9	300	146	178	211	195	179	187	187
11	169	97	81	193	192	176	184	156
13	152	88	64	170	232	152	168	147
15	200	96	104	191	135	119	143	141
17	138	57	97	170	186	176	186	145
19	250	169	113	242	210	177	185	192
21	202	191	153	161	153	202	176	174
23	209	136	225	201	192	192	200	194
25	174	111	103	190	206	174	190	164
27	174	127	87	167	182	167	167	153
29	186	97	105	211	202	170	186	165

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-13. Total BOD_5 analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1800	2000-2100	2400-0100	X *
1	160	90	46	230	170	200	220	159
3	180	68	94	200	140	150	170	143
5	150	190	<75	210	100	180	240	<149
7	210	75	83	330	260	200	210	195
9	230	68	160	160	240	190	270	181
11	200	-	-	200	140	170	220	
13	160	190	<75	160	180	200	220	<169
15	280	110	83	400	160	150	230	216
17	220	<75	160	230	180	230	410	<215
19	210	120	75	290	180	190	230	185
21	230	110	75	220	160	190	230	174
23	190	73	97	180	160	200	160	151
25	230	92	68	220	200	150	160	156
27	250	140	110	230	200	150	210	184
29	220	68	75	230	150	160	200	158

* X - Daily average (calculation excludes last column)

Table A-14. "Dissolved" BOD_5 analyses for sampling hours of June 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
1	74	24	18	77	65	60	60	54
3	90	30	18	84	58	60	58	57
5	24	33	<30	67	95	57	84	<57
7	63	18	27	72	93	84	100	65
9	110	<30	21	72	84	72	90	<68
11	84	-	-	84	62	85	100	
13	90	40	<50	77	78	70	90	<71
15	120	45	45	110	42	60	78	71
17	74	100	85	68	87	39	84	80
19	45	33	35	27	32	32	18	57
21	28	15	29	58	34	12	29	59
23	57	93	39	74	75	55	75	68
25	72	70	58	75	72	55	77	61
27	72	63	87	84	63	48	58	46
29	75	85	83	90	62	69	82	60

* X - Daily average (calculation excludes last column)

Table A-15. Total suspended solids analyses for sampling hours of June 1971

Date	Hour of Day - kg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
1	224	132	116	364	164	106	298	191
3	150	90	138	190	190	180	180	160
5	116	60	30	390	90	240	342	181
7	202	122	162	166	416	318	170	265
9	130	98	140	262	214	158	458	209
11	234	96	72	266	164	198	210	178
13	210	86	60	212	208	198	226	171
15	256	110	132	480	238	190	270	239
17	214	46	220	170	274	398	440	252
19	202	102	80	332	238	190	200	192
21	208	104	112	440	186	208	104	195
23	194	102	100	186	298	152	220	159
25	206	118	146	274	178	218	194	191
27	200	86	106	282	220	160	236	183
29	202	86	84	268	172	214	194	177

* X - Daily average (calculation excludes last column)

Table A-16. Total alkalinity analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l as $CaCO_3$							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
1	180	192	205	199	183	174	173	187
3	174	176	194	197	179	194	195	187
5	274	184	188	255	174	173	171	203
7	176	181	195	185	174	171	156	177
9	173	173	199	201	184	171	168	181
11	174	161	175	189	166	154	164	166
13	164	170	175	208	270	167	166	189
15	171	167	250	189	165	155	157	179
17	162	160	160	185	189	158	166	169
19	164	168	180	290	175	173	171	189
21	170	171	170	170	172	180	174	172
23	171	169	183	161	167	165	158	168
25	168	160	168	188	210	170	168	176
27	170	174	156	225	173	167	172	177
29	167	166	169	181	178	159	174	171

* $\bar{X}$ - Daily average (calculation excludes last column)

Table A-17. Chloride analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l as NaCl							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
1	53	48	51	67	63	55	59	53
3	52	51	54	75	59	58	53	57
5	55	50	52	56	61	60	53	54
7	56	53	55	59	61	63	57	56
9	64	64	58	56	59	61	56	56
11	54	52	59	57	71	65	55	61
13	56	56	61	56	59	58	58	58
15	70	53	56	59	73	73	70	65
17	61	59	56	70	72	70	64	65
19	77	54	62	52	60	58	58	60
21	60	56	73	56	61	67	58	63
23	70	63	77	72	75	75	78	76
25	72	67	115	67	68	68	91	82
27	56	61	76	58	64	70	58	63
29	64	75	79	70	71	99	61	74

* $\bar{X}$ - Daily average (calculation excludes last column)

Table A-18. Total hardness analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l as $CaCO_3$							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
1	156	188	202	156	134	141	139	159
3	137	163	180	143	134	136	135	147
5	128	152	167	126	123	125	130	136
7	126	156	169	142	124	126	140	141
9	133	144	163	127	120	130	123	134
11	121	159	158	127	120	121	121	132
13	125	140	164	174	134	126	123	135
15	123	137	154	122	126	125	123	130
17	120	114	153	121	110	124	122	123
19	121	131	152	122	121	119	119	126
21	122	136	148	126	152	153	153	141
23	132	151	167	129	126	126	126	137
25	125	141	158	124	122	124	127	136
27	127	136	156	127	120	126	122	131
29	123	153	155	128	127	131	121	134

* X - Daily average (calculation excludes last column)

Table A-19. Total nitrogen analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
7	24.7	17.8	26.4	38.5	25.4	22.5	21.3	25.2
9	23.5	20.0	27.2	38.0	26.1	27.6	27.2	27.1
11	-	-	-	-	24.5	22.5	25.5	-
13	20.0	19.5	27.1	30.4	22.7	23.3	26.4	24.2
15	20.1	21.5	26.7	56.2	22.7	21.5	23.0	27.4
17	25.4	14.3	30.5	34.4	25.2	24.6	34.7	27.1
19	24.6	23.7	20.5	36.3	25.7	16.0	26.0	26.1
21	26.2	24.9	22.2	35.1	18.7	22.8	22.5	24.6
23	23.8	20.5	22.3	32.2	21.2	21.7	23.8	23.5
25	23.8	16.2	24.0	35.9	22.0	24.5	22.1	24.1
27	23.5	22.1	17.5	44.5	25.3	25.9	26.7	26.5
29	25.6	16.9	21.5	36.6	22.5	22.6	20.3	23.6

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-20. Total phosphorus analytical results for sampling hours of June 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
1	7.8	6.1	3.7	8.2	16.3	11.8	10.9	9.3
3	10.3	6.9	4.7	13.2	14.2	10.5	10.8	10.1
5	11.1	6.1	3.2	18.5	16.3	12.1	16.5	12.0
7	5.1	11.9	5.5	20.0	14.3	11.7	10.6	11.3
9	10.9	6.6	6.5	17.1	14.7	11.4	11.4	11.1
11	10.3	3.9	3.1	14.8	13.5	10.8	10.6	9.6
13	9.3	6.0	4.5	10.7	11.9	10.7	9.5	9.0
15	10.3	6.4	5.0	26.7	19.3	12.3	11.6	13.1
17	11.4	4.3	9.2	21.6	16.3	12.8	12.2	12.5
19	8.6	6.4	4.6	17.0	16.3	11.6	10.0	10.6
21	11.0	7.1	5.7	15.6	12.6	12.5	9.8	12.5
23	10.8	5.8	5.2	13.5	13.5	11.2	11.8	10.3
25	10.6	5.6	4.8	16.3	13.7	12.2	9.7	10.4
27	9.3	3.7	2.5	10.6	11.0	10.7	10.2	8.3
29	9.7	3.9	4.6	14.4	13.5	16.3	10.6	10.4

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-21. Average sewer flows for sampling hours of July 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
9	6.6 (289)	2.6 (125)	2.7 (118)	8.0 (350)	7.2 (315)	6.9 (302)	6.1 (267)	5.7 (250)
11	5.7 (250)	3.2 (140)	2.4 (105)	6.9 (302)	6.9 (302)	6.0 (263)	6.4 (283)	5.2 (228)
13	6.6 (289)	2.7 (118)	2.7 (118)	7.9 (346)	6.9 (302)	6.6 (289)	6.4 (280)	5.6 (245)
15	6.2 (272)	3.2 (140)	2.9 (127)	8.4 (368)	7.1 (311)	7.1 (311)	6.9 (302)	5.8 (254)
17	6.1 (267)	3.6 (158)	2.8 (123)	8.2 (359)	7.1 (311)	6.4 (280)	6.0 (264)	5.7 (250)
19	6.2 (272)	2.9 (127)	2.9 (127)	9.0 (394)	7.6 (329)	6.7 (293)	7.5 (329)	5.9 (258)
21	-	-	2.8 (123)	8.0 (350)	6.9 (302)	6.9 (302)	6.7 (293)	-
23	6.9 (302)	3.2 (140)	2.9 (127)	8.6 (377)	7.8 (342)	7.1 (311)	6.7 (293)	6.1 (267)
25	6.7 (293)	3.5 (153)	2.7 (118)	7.5 (329)	7.4 (324)	6.4 (280)	6.6 (289)	5.7 (250)
27	7.5 (329)	2.8 (123)	2.9 (127)	8.2 (359)	6.6 (289)	7.4 (324)	7.1 (311)	5.9 (258)
29	11.2 (512)	6.4 (280)	6.0 (264)	10.2 (447)	10.1 (442)	8.8 (385)	8.2 (359)	8.8 (385)

* $\bar{X}$ - Daily average (calculation excludes last column)

Table A-22. Total COD analytical results for sampling hours of July 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
7	577	279	-	637	503	462	804	547
9	606	505	343	626	646	585	545	536
11	606	282	182	585	625	525	645	493
13	623	302	342	663	660	480	620	513
15	646	202	343	585	405	646	667	511
17	485	202	162	566	545	626	505	442
19	645	303	222	1010	460	440	520	500
21	586	303	505	454	707	525	545	519
23	625	202	323	666	620	520	680	505
25	600	160	120	600	660	460	540	420
27	640	180	440	560	848	625	505	528
29	283	212	162	384	184	440	779	336
31	543	741	140	-	1246	342	422	489

* X - Daily average (calculation excludes last column)

Table A-23. "Dissolved" COD analytical results for sampling hours of July 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	X *
7	191	96	-	175	217	159	177	171
9	193	105	113	193	227	194	308	160
11	162	73	122	154	186	146	178	146
13	209	96	136	281	208	200	184	188
15	186	81	113	186	194	202	219	169
17	177	64	32	153	177	153	177	111
19	177	105	72	169	192	176	192	155
21	169	97	89	202	219	161	129	152
23	153	72	81	177	84	160	178	136
25	136	24	48	128	98	160	152	107
27	200	72	136	168	161	146	153	148
29	105	40	40	105	115	90	90	84
31	112	56	48	-	1946	342	422	371

* X - Daily average (calculation excludes last column)

Table A-24. Total BOD_5 analytical results for sampling hours of July 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
7	200	83	-	190	150	190	220	
9	200	130	94	160	180	190	[illegible]	164
11	210	98	83	90	240	210	220	164
13	240	98	110	210	130	150	190	168
15	220	68	100	120	190	220	260	131
17	180	<75	<75	190	220	180	190	<159
19	190	120	<75	180	180	170	200	<159
21	220	100	82	150	210	210	310	183
23	250	75	90	210	140	150	210	161
25	180	<75	<75	170	210	220	200	<161
27	260	<75	100	170	150	240	230	<175
29	67	<75	93	150	130	110	150	<100
31	110	<75	<75	-	250	130	150	

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-25. "Dissolved" BOD_5 analytical results for sampling hours of July 1971 [a]

Date	Hour of Day - mg/l								
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$	s
7	83	20	-	59	72	45	69		
9	57	28	32	60	75	93	120	66	
11	96	32	21	84	76	87	63	66	
13	100	26	75	78	72	72	72	71	
15	81	14	26	72	80	92	110	68	
17	80	<15	<15	66	69	59	72	<53	
19	69	32	<15	57	81	66	80	<57	
21	87	32	22	66	60	75	99	63	
23	98	16	21	99	69	71	72	68	
25	61	<15	<15	45	76	66	64	<49	
27	75	<15	27	57	63	69	78	<55	
29	<30	<6	9	36	45	21	21	<24	
31	33	<15	<15	-	64	42	54		

a $\bar{X}$ = Daily average (calculation excludes last column)

Table A-26. Total suspended solids analytical results for sampling hours of July 1971

Date	Hour of Day - mg/l							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
7	196	132	-	242	198	226	238	205
9	212	122	160	296	198	216	116	189
11	220	126	70	264	284	212	242	203
13	186	102	184	294	190	174	188	188
15	214	80	108	262	210	154	210	177
17	260	104	96	606	214	214	244	251
19	192	126	124	268	150	136	134	136
21	170	88	146	232	290	202	274	200
23	334	82	180	206	176	182	204	207
25	178	42	52	224	244	236	170	164
27	222	96	194	204	148	160	166	170
29	154	80	77	326	76	96	148	137
31	186	98	166	-	476	246	218	191

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-27. Total alkalinity analytical results for sampling hours of July 1971

Date	Hour of Day - mg/l as $CaCO_3$							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
7	166	168	-	198	188	156	167	176
9	164	164	170	169	178	170	168	173
11	164	173	169	210	177	175	175	178
13	160	153	165	187	162	156	157	164
15	157	160	171	181	160	166	161	166
17	167	159	160	212	188	180	170	178
19	170	168	176	186	184	195	160	180
21	152	170	170	170	177	190	172	170
23	167	164	167	190	186	166	173	172
25	174	178	178	212	174	170	173	181
27	110	168	174	196	209	175	178	183
29	220	220	223	206	172	201	199	207
31	194	202	234	220	190	182	178	206

* $\bar{X}$ - Daily average (calculation excludes last column)

Table A-28. Chloride analytical results for sampling hours of July 1971

Date	Hour of Day - mg/l as NaCl							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
7	58	51	-	59	58	75	55	61
9	59	53	61	64	74	59	82	65
11	62	58	61	58	61	59	59	60
13	77	43	55	75	73	72	73	67
15	73	61	59	69	70	80	61	70
17	61	61	61	60	62	63	63	62
19	63	56	60	66	63	64	50	61
21	57	56	61	70	76	61	56	62
23	61	52	61	67	65	59	56	60
25	56	53	55	60	56	61	59	57
27	54	50	51	55	56	53	56	54
29	53	49	52	56	58	55	55	54
31	52	53	50	52	59	52	52	53

* $\bar{X}$ = Daily average (calculation excludes last column)

Table A-29. Total hardness analytical results for sampling hours of July 1971

Date	Hour of Day - mg/l as $CaCO_3$							
	0000-0100	0400-0500	0800-0900	1200-1300	1600-1700	2000-2100	2400-0100	$\bar{X}$ *
7	134	162	-	119	119	119	112	129
9	116	139	145	139	111	118	121	127
11	116	128	148	126	125	120	120	126
13	114	128	141	130	124	117	120	125
15	120	146	141	123	125	120	120	126
17	116	143	145	122	122	117	116	126
19	122	127	146	130	120	118	120	126
21	122	140	151	155	120	123	115	132
23	117	126	139	118	119	121	115	122
25	143	166	168	139	122	127	131	148
27	119	156	152	126	123	122	126	132
29	275	326	301	205	214	216	219	251
31	180	204	242	247	150	150	152	189

* $\bar{X}$ - Daily average (calculation excludes last column)

Table A-30. Precipitation record for the latter part of May and for June 1971

Date	Hour	Amount	
		Inches	mm
5/27	0100 - 0200	0.12	3.0
	0200 - 0300	1.96	49.5
	0300 - 0400	0.45	11.4
	0400 - 0500	0.05	1.3
		2.57	65.2
5/29	0400 - 0500	0.01	0.3
	0500 - 0600	0.04	1.0
	0600 - 0700	0.06	1.5
	0700 - 0800	0.25	6.4
	0800 - 0900	0.50	12.7
	0900 - 1000	0.13	3.3
	1900 - 2000	0.01	0.3
		1.00	25.5
6/1	0600 - 0700	0.03	0.8
	0700 - 0800	0.42	10.7
	0800 - 0900	0.06	1.5
	0900 - 1000	0.04	1.0
	1000 - 1100	0.03	0.8
		0.58	14.8
6/28	1000 - 1100	0.05	1.3
	1100 - 1200	0.45	11.4
	1600 - 1700	0.24	6.1
		0.74	18.8

Table A-31. Precipitation record for July 1971

Date	Hour	Amount	
		Inches	mm
7/2	0200 - 0300	0.07	1.8
	0600 - 0700	0.01	0.3
	1900 - 2000	0.52	13.2
	2000 - 2100	0.04	1.0
	2100 - 2200	0.03	0.8
		0.67	17.1
7/19	1000 - 1100	0.23	5.8
	1100 - 1200	0.02	0.5
		0.25	6.3
7/23	2100 - 2200	0.24	6.1
	2200 - 2300	0.02	0.5
		0.26	6.6
7/24	0400 - 0500	0.02	0.5
	1000 - 1100	0.80	20.3
		0.82	20.8
7/27	0400 - 0500	0.01	0.3
	0500 - 0600	0.05	1.2
	1100 - 1200	0.01	0.3
	1400 - 1500	0.07	1.8
		0.14	3.6
7/28	0600 - 0700	0.26	6.6
	0700 - 0800	1.05	26.7
	0800 - 0900	0.02	0.5
	0900 - 1000	0.01	0.3
	1000 - 1100	0.31	7.9
	1100 - 1200	0.36	9.1
	1200 - 1300	0.20	5.1
	1300 - 1400	0.04	1.0
	1600 - 1700	0.02	0.5
		2.27	57.7
7/29	0900 - 1000	0.25	6.3
	2200 - 2300	0.02	0.5
		0.27	6.8

Table A-32. Total Plant Flow Data, October 19, 1971

Flow Through Flume # 1

11:30-12:50 = 80 min.	4.8 MGD = 3340 GPM =	266	Thousand Gallons
1:30-2:30 = 60 min.	4.8 MGD = 3340 GPM =	200	" "
2:30-3:00 = 30 min.	6.0 MGD = 4160 GPM =	125	" "
3:00-4:15 = 75 min.	5.0 MGD = 3470 GPM =	260	" "
Total Flow Through Flume # 1		851	Thousand Gallons

Flow Through Flume # 2

11:30-12:50 = 80 min.	3.8 MGD = 2640 =	211	Thousand Gallons
1:30-2:30 = 60 min.	4.2 MGD = 2910 =	174	" "
2:30-3:00 = 30 min.	5.0 MGD = 3470 =	104	" "
3:00-4:15 = 75 min.	4.0 MGD = 2780 =	209	" "
Total Flow Through Flume # 2		698	Thousand Gallons

Flow Through Flume # 3

11:30-12:50 = 80 min.	4.2 MGD = 2910 =	233	Thousand Gallons
1:30-2:30 = 60 min.	4.8 MGD = 3340 =	200	" "
2:30-3:00 = 30 min.	6.0 MGD = 4160 =	125	" "
3:00-4:15 = 75 min.	5.0 MGD = 3470 =	260	" "
Total Flow Through Flume # 3		818	Thousand Gallons

Grand Total = 2.367 Million Gallons
or approximately 2.4 million gallons

Table A-33. Total Plant Flow Data, October 20, 1971

Flow Through Flume # 1

10:20-10:30 = 10 min. 5.0 MGD = 3470 GPM =	34.7	Thousand	Gallons
10:40-10:50 = 10 min. 4.8 MGD = 3340 GPM =	33.4	"	"
1:15-2:45 = 90 min. 4.8 MGD = 3340 GPM =	300	"	"
2:45-4:10 = 85 min. 4.0 MGD = 2780 GPM =	236	"	"
Total Flow Through Flume # 1	604	Thousand	Gallons

Flow Through Flume # 2

10:20-10:30 = 10 min. 4.4 MGD = 3060 GPM =	30.6	Thousand	Gallons
10:40-10:50 = 10 min. 4.4 MGD = 3060 GPM =	30.6	"	"
1:15-2:45 = 90 min. 4.0 MGD = 2780 GPM =	250	"	"
2:45-4:10 = 85 min. 3.75 MGD = 2600 GPM =	221	"	"
Total Flow Through Flume # 2	532	Thousand	Gallons

Flow Through Flume # 3

10:20-10:30 = 10 min. 5.0 = 3470 GPM =	34.7	Thousand	Gallons
10:40-10:50 = 10 min. 4.8 = 3340 GPM =	33.4	"	"
1:15-2:45 = 90 min. 4.6 = 3200 GPM =	288	"	"
2:45-4:10 = 85 min. 4.0 = 2780 GPM =	236	"	"
Total Flow Through Flume # 3	592	Thousand	Gallons

Grand Total = 1.728 Million Gallons
or approximately 1.7 million gallons

Table A-34. Stormwater Evaluation Plan

RUN	BASIN NOS.	FLOW MGD	OPERATION
1	1 & 2	4 ea.	∿ 600 mg/l sludge
2	1 & 2	4 ea.	3-400 mg/l sludge
3	1 & 2	4 ea.	8-900 mg/l sludge
4	1 & 2	8 ea.	∿ 600 mg/l sludge
5	1 & 2	8 ea.	3-400 mg/l sludge
6	1 & 2	8 ea.	8-900 mg/l sludge
7	1 & 3	4 ea.	∿ 600 mg/l sludge in #1, nothing in #3
8	2 & 3	4 ea.	∿ 600 mg/l sludge in #2, nothing in #3
9	1 & 3	8 ea.	∿ 600 mg/l sludge in #1, nothing in #3
10	2 & 3	8 ea.	∿ 600 mg/l sludge in #2, nothing in #3

All basins chlorinated.

Supplemental chemical treatment will be needed when above completed.

Choice of runs up to Project Engineer -- as the situation permits.